40TH CONGRESS, 3d Session. | HOUSE OF REPRESENTATIVES. | Ex. Doc. No. 83.

ANNUAL REPORT

OF

THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1868.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1869.

IN THE SENATE OF THE UNITED STATES.

MARCH 1, 1869.

Resolved, That five thousand copies of the report of the Smithsonian Institution for the year eighteen hundred and sixty-eight be printed—three thousand for the use of the Senate, and two thousand for the Institution; and that said report be stereotyped: *Provided*, That the aggregate number of pages of said report shall not exceed four hundred and fifty, without illustrations, except those furnished by the Institution.

IN THE HOUSE OF REPRESENTATIVES.

FEBRUARY 27, 1869.

Resolved, That there be printed five thousand extra copies of the report of the Smithsonian Institution—three thousand for the use of the House, and two thousand for the Institution—the same to be stereotyped at the expense heretofore provided for.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The annual report of the Smithsonian Institution for the year 1868.

FEBRUARY 13, 1869.—Laid on the table and ordered to be printed.

SMITHSONIAN INSTITUTION,
Washington, February 3, 1869.

SIR: In behalf of the Board of Regents I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1868.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. B. F. WADE,
President of the Senate.

Hon. SCHUYLER COLFAX,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1868.

To the Senate and House of Representatives:

In obedience to the act of Congress of August 10, 1846, establishing the Smithsonian Institution, the undersigned, in behalf of the Regents, submit to Congress, as a report of the operations, expenditures, and condition of the Institution, the following documents:

1. The Annual Report of the Secretary, giving an account of the operations of the Institution during the year 1868.
2. Report of the Executive Committee.
3. Proceedings of the Board of Regents.
4. Appendix.

Respectfully submitted.

S. P. CHASE, *Chancellor.*
JOSEPH HENRY, *Secretary.*

OFFICERS OF THE SMITHSONIAN INSTITUTION.

FEBRUARY, 1869.

ANDREW JOHNSON, *ex officio* Presiding Officer of the Institution.
SALMON P. CHASE, Chancellor of the Institution.
JOSEPH HENRY, Secretary of the Institution.
SPENCER F. BAIRD, Assistant Secretary.
WILLIAM J. RHEES, Chief Clerk.
RICHARD DELAFIELD, }
PETER PARKER, } Executive Committee.
JOHN MACLEAN, }

REGENTS OF THE INSTITUTION.

B. F. WADE, Vice-President of the United States, (*pro tempore.*)
S. P. CHASE, Chief Justice of the United States.
S. J. BOWEN, Mayor of the City of Washington.
L. TRUMBULL, member of the Senate of the United States.
GARRETT DAVIS, member of the Senate of the United States.
W. P. FESSENDEN, member of the Senate of the United States.
J. A. GARFIELD, member of the House of Representatives.
L. P. POLAND, member of the House of Representatives.
J. V. L. PRUYN, member of the House of Representatives.
W. B. ASTOR, citizen of New York.
T. D. WOOLSEY, citizen of Connecticut.
L. AGASSIZ, citizen of Massachusetts.
JOHN MACLEAN, citizen of New Jersey.
RICHARD DELAFIELD, citizen of Washington.
PETER PARKER, citizen of Washington.

MEMBERS EX OFFICIO OF THE INSTITUTION.

ANDREW JOHNSON, President of the United States.

B. F. WADE, Vice-President of the United States, (*pro tempore.*)

W. H. SEWARD, Secretary of State.

H. McCULLOCH, Secretary of the Treasury.

JOHN M. SCHOFIELD, Secretary of War.

G. WELLES, Secretary of the Navy.

A. W. RANDALL, Postmaster General.

WM. M. EVARTS, Attorney General.

S. P. CHASE, Chief Justice of the United States.

ELISHA FOOTE, Commissioner of Patents.

S. J. BOWEN, Mayor of the City of Washington.

HONORARY MEMBER.

O. H. BROWNING, Secretary of the Interior, (*ex officio.*)

PROGRAMME OF ORGANIZATION

OF THE

SMITHSONIAN INSTITUTION.

[PRESENTED IN THE FIRST ANNUAL REPORT OF THE SECRETARY, AND ADOPTED BY THE BOARD OF REGENTS, DECEMBER 13, 1847.]

INTRODUCTION.

General considerations which should serve as a guide in adopting a Plan of Organization.

1. WILL OF SMITHSON. The property is bequeathed to the United States of America, "to found at Washington, under the name of the SMITHSONIAN INSTITUTION, an establishment for the increase and diffusion of knowledge among men."

2. The bequest is for the benefit of mankind. The government of the United States is merely a trustee to carry out the design of the testator.

3. The Institution is not a national establishment, as is frequently supposed, but the establishment of an individual, and is to bear and perpetuate his name.

4. The objects of the Institution are, 1st, to increase, and, 2d, to diffuse knowledge among men.

5. These two objects should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths; and the second, to disseminate knowledge, thus increased, among men.

6. The will makes no restriction in favor of any particular kind of knowledge; hence all branches are entitled to a share of attention.

7. Knowledge can be increased by different methods of facilitating and promoting the discovery of new truths; and can be most extensively diffused among men by means of the press.

8. To effect the greatest amount of good, the organization should be such as to enable the Institution to produce results, in the way of increasing and diffusing knowledge, which cannot be produced either at all or so efficiently by the existing institutions in our country.

9. The organization should also be such as can be adopted provisionally; can be easily reduced to practice; receive modifications, or be abandoned, in whole or in part, without a sacrifice of the funds.

10. In order to compensate, in some measure, for the loss of time occasioned by the delay of eight years in establishing the Institution, a considerable portion of the interest which has accrued should be added to the principal.

11. In proportion to the wide field of knowledge to be cultivated, the funds are small. Economy should, therefore, be consulted in the construction of the building; and not only the first cost of the edifice should

be considered, but also the continual expense of keeping it in repair, and of the support of the establishment necessarily connected with it. There should also be but few individuals permanently supported by the Institution.

12. The plan and dimensions of the building should be determined by the plan of the organization, and not the converse.

13. It should be recollected that mankind in general are to be benefited by the bequest, and that, therefore, all unnecessary expenditure on local objects would be a perversion of the trust.

14. Besides the foregoing considerations, deduced immediately from the will of Smithson, regard must be had to certain requirements of the act of Congress establishing the Institution. These are, a library, a museum, and a gallery of art, with a building on a liberal scale to contain them.

SECTION I.

Plan of organization of the Institution in accordance with the foregoing deductions from the will of Smithson.

TO INCREASE KNOWLEDGE. It is proposed—

1. To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and,

2. To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

TO DIFFUSE KNOWLEDGE. It is proposed—

1. To publish a series of periodical reports on the progress of the different branches of knowledge; and,

2. To publish occasionally separate treatises on subjects of general interest.

DETAILS OF THE PLAN TO INCREASE KNOWLEDGE.

I. *By stimulating researches.*

1. Facilities afforded for the production of original memoirs on all branches of knowledge.

2. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled Smithsonian Contributions to Knowledge.

3. No memoir on subjects of physical science to be accepted for publication which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

4. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

5. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision is made.

6. The volumes of the memoirs to be exchanged for the transactions of literary and scientific societies, and copies to be given to all the colleges and principal libraries in this country. One part of the remaining copies may be offered for sale, and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

7. An abstract, or popular account, of the contents of these memoirs to be given to the public through the annual report of the Regents to Congress.

II. *By appropriating a part of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects; so that in course of time each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made.

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts accumulated in the offices of government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches, and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

DETAILS OF THE PLAN FOR DIFFUSING KNOWLEDGE.

I. *By the publication of a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. These reports will diffuse a kind of knowledge generally interesting, but which, at present, is inaccessible to the public. Some of the reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons intersted in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress, for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world; penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. *By the publication of separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.
2. The treatises should, in all cases, be submitted to a commission of competent judges previous to their publication.
3. As examples of these treatises, expositions may be obtained of the present state of the several branches of knowledge mentioned in the table of reports.

SECTION II.

Plan of organization, in accordance with the terms of the resolutions of the Board of Regents providing for the two modes of increasing and diffusing knowledge.

1. The act of Congress establishing the Institution contemplated the formation of a library and a museum; and the Board of Regents, including these objects in the plan of organization, resolved to divide the income into two equal parts.
2. One part to be appropriated to increase and diffuse knowledge by means of publications and researches, agreeably to the scheme before given. The other part to be appropriated to the formation of a library and a collection of objects of nature and of art.
3. These two plans are not incompatible with one another.
4. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies in the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

5. The Institution should make special collections, particularly of objects to illustrate and verify its own publications.

6. Also, a collection of instruments of research in all branches of experimental science.

7. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found in the United States.

8. Also, catalogues of memoirs, and of books and other materials, should be collected for rendering the Institution a centre of bibliographical knowledge, whence the student may be directed to any work which he may require.

9. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and, therefore, it will seldom be necessary to purchase articles of this kind.

10. Attempts should be made to procure for the gallery of art casts of the most celebrated articles of ancient and modern sculpture.

11. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union and other similar societies.

12. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, &c.

13. For the present, or until the building is fully completed, besides the Secretary, no permanent assistant will be required, except one, to act as librarian.

14. The Secretary, by the law of Congress, is alone responsible to the Regents. He shall take charge of the building and property, keep a record of proceedings, discharge the duties of librarian and keeper of the museum, and may, with the consent of the Regents, *employ assistants.*

15. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art. Distinguished individuals should also be invited to give lectures on subjects of general interest.

This programme, which was at first adopted provisionally, has become the settled policy of the Institution. The only material change is that expressed by the following resolutions, adopted January 15, 1855, viz:

Resolved, That the 7th resolution passed by the Board of Regents, on the 26th of January, 1847, requiring an equal division of the income between the active operations and the museum and library, when the buildings are completed, be, and it is hereby, repealed.

Resolved, That hereafter the annual appropriations shall be apportioned specifically among the different objects and operations of the Institution, in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance and a compliance in good faith with the law.

REPORT

OF

PROFESSOR HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR

1868.

To the Board of Regents:

GENTLEMEN: Nothing has occurred during the past year of a character demanding the special action of the Board. Indeed, the policy of the Institution originally adopted has become so firmly settled and so widely known, as well as properly appreciated, that few difficulties are now likely to present themselves in the administration of the trust which do not find a solution in some precedent in the experience of the past. The funds appropriated at the last session have been devoted to the different objects for which they were designated, and the several classes of operations which were inaugurated at the commencement of the Institution have been prosecuted with as much efficiency as the means at disposal would permit. From the first there has been no want of unoccupied fields inviting attention, and well adapted with judicious cultivation to yield a plentiful harvest of additions to science. Indeed, the only subject of regret suggested by a review of the past, or a survey of the present, is the application of so large a portion of the income to objects which, though in most cases important in themselves, are not, as is now generally conceded, strictly reconcilable either with the scope or the terms of the endowment. The guardians of the Institution are not, however, responsible for these expenditures, which had their origin in a general misconception of the import of the bequest at the time when Congress enacted the law organizing the Institution. On the contrary, the administration has been such as to correct, as far as possible, the errors above mentioned, and to present to the world an example worthy of imitation in the management of other establishments founded on trust funds. The directors have ever been deeply impressed with a sense of the importance of the trust committed to their charge, not only in consideration of the good which might directly result from it, but also on account of the influence which so conspicuous, and in many respects so original an enterprise, could not fail to have upon the world. Man is an imitative being, and among the many individuals in this country who have accumulated princely fortunes

by the energetic exercise of native talents, there are probably not a few who only need the assurance of a successful precedent to induce them to emulate the liberality of Smithson in the endowment of other institutions for the advancement of knowledge.

At the last session of the board it was resolved that a memorial should be presented to Congress, setting forth the large expenditure to which the Institution had been subjected by reason of the accommodation and maintenance of the National Museum, and asking that the usual appropriation of $4,000 which had been made on account of these objects might be increased to $10,000; also that $25,000 might be appropriated towards fitting up the large room in the second story of the main building for the better exhibition of the government collections. In accordance with this resolution the petition was prepared, signed by the Chancellor and Secretary of the Institution, and presented to the House of Representatives by General Garfield, one of the regents. It was referred to the Committee on Appropriations, and although forcibly and eloquently advocated by the members of the Board of Regents belonging to the House, it was not granted, and only the usual appropriation of $4,000 was made. The reasonableness of this petition, which I doubt not under a better condition of the national finances will meet with a more favorable reception, must be manifest when it is considered that $4,000 is the sum which the maintenance of the museum cost the government when it was under the charge of the Patent Office, and that since its removal to the Institution it has been enlarged to threefold its previous size, while the money has been depreciated to one-half its former value; and furthermore, that the amount expended since the fire in 1865, for the reconstruction of the building and supply of furniture, is over $140,000, the greater part of which was for the accommodation of the National Museum. This large sum was rendered necessary by the peculiar character of the architecture, the cost of fire-proof materials, and the high price of labor. Of the above amount, more than $20,000 was defrayed from the annual income of last year, and after this reduction of the resources it was scarcely to be expected that the operations of the Institution could be carried on with as much efficiency as had been the case in years previous to the disaster which entailed on it this heavy incidental expenditure. Yet we venture to hope that the exposition given in the following parts of this report will show the results attained to have been little inferior in value or extent to those of any preceding year.

It will appear from the report of the Executive Committee, that notwithstanding the large draughts which have been made upon the funds on account of the building, they are still in a highly prosperous condition. Thus, while at the beginning of the year 1868 there was a balance in the treasury of about $11,000, with outstanding liabilities contracted principally for repairs and reconstruction to the amount of $22,000; on the other hand, at the beginning of 1869, there is a disposable balance of

$10,352, with bills falling due to the amount of not more than $3,000. The funds are therefore in a better condition at present than they were a year ago by upwards of $18,000. The Institution having paid all indebtedness incurred by repairs on the building, could to-day wind up its affairs not only without debt, but with the capital exhibited in the following statement:

The whole bequest of Smithson, in United States treasury..	$541,379 63
Additions from savings, &c., in United States treasury...	108,620 37
Virginia State stock, $72,760, valued at..................	40,000 00
Cash on hand..	7,000 00
Total capital..	697,000 00

While every part of the original programme has been rigidly carried out, the large increase in the capital exhibited in the foregoing statement may justly be claimed as the result of frugal management and a judicious investment of the interest annually accruing.

At the commencement of operations definite lines of policy were adopted, the object of which was to insure the expenditure of the income in such a manner as most effectually to realize the conceptions of the founder in his generous purpose of promoting the "increase and diffusion of knowledge among men." Of the principles judged conducive to this end an important one was embodied in the resolution to co-operate, as far as possible, with individuals and institutions engaged in the same work, especially with those in the city of Washington. An obvious corollary of this was the determination to make no appropriation of the funds to the furtherance or support of any object which could be accomplished as well by other instrumentality. This policy has been frequently referred to in previous reports under the concisely expressed motto, "co-operation not monopoly."

It was in the spirit of this policy that the books of the Institution were last year incorporated with those of Congress and results produced which fully justify the measure as well as illustrate the importance of the principle; for, while by this union under one system and superintendence a library has been formed worthy the National Capital, the capacity of the Smithsonian fund to advance knowledge has been materially increased. In pursuance of the same policy another important arrangement has been made during the past year. I refer to the transfer of the herbarium of the Institution to the care of the Department of Agriculture. This herbarium consists of from 15,000 to 20,000 specimens from all parts of the world, properly classified and labeled. It is the result, in the line of botany, of the various expeditions of the government and of the special explorations of the Institution. The collections have from the first been in the charge of Dr. Gray and Dr. Torrey—the two most eminent botanists in this country—who have scientifically arranged them and formed

the duplicates into sets for distribution. Dr. Gray has, however, left the country for an absence of some years in Europe, and Dr. Torrey, who has devoted at least two entire years of his life to these specimens, is unable longer to continue this gratuitous and disinterested service on account of the more imperious duties of his official position, and consequently intimated to us that the botanical specimens would have to be removed from Columbia College, New York, where they have been deposited under his care. To render such a collection of any practical use, and to preserve the plants from decay, the constant superintendence of a competent botanist is obviously indispensable; but as the appropriation hitherto made by Congress is far too meagre to meet the cost of the present support of the museum it was necessary to seek some other means of providing for these plants. Now, as the Agricultural Department requires for continual reference such a collection of plants, and had begun to gather one; and as, also, in the course of its investigations it has need of the services of a practical botanist, nothing could seem more advisable than to unite the two collections. By this arrangement not only are the series of plants themselves rendered more perfect and more readily accessible, but the Institution is in the same degree relieved of the burden imposed upon it in the support of a multifarious and rapidly increasing museum. The transfer, however, is made with the understanding that the superintending botanist shall be approved by the Institution, that the collection shall be accessible to the public for practical or educational purposes, and to the Institution for scientific investigation or for supplying any information that may be asked for by its correspondents in regard to the names and character of plants. It is further stipulated that due credit shall be given to the Institution in the publications of the department for the deposit of the original specimens as well as for the additions which from time to time may be made to them by the Institution.

Agreeably to the policy above mentioned, the Institution has also entered into an arrangement with the medical department of the United States army by which it was thought mutual convenience and harmonious co-operation would be promoted. By this arrangement the Institution transfers to the museum in charge of the Surgeon General its large collection of human crania, and also all its specimens pertaining to anatomy, physiology, medicine, and surgery, while it takes, in return, from the medical museum all the collections which more properly relate to ethnology. It will be seen that the object kept constantly in view in these transactions is to render the various collections in Washington, which have been made under the direction of the government and the Institution, definite parts of one harmonious system, and at the same time to avoid the loss of labor and of means, in duplicating and preserving articles of a similar character in separate establishments.

The disposition, which up to this time, has been made of the plants illustrates the plan which was adopted, from the first, in order to pro-

duce the most important results with a given expenditure of means. The funds of the Institution, it was seen, were not sufficient to carry out all the objects contemplated in the original law of organization. To sustain properly a national museum and render it an efficient means of popular instruction would require a number of professors of the different branches into which natural history has been divided. But, as the income was manifestly insufficient for this purpose, the plan was adopted of calling in, as far as possible, the aid of individual collaborators and of other institutions. Agreeably to this principle of action the plants were given in charge, as has been stated, to Doctors Gray and Torrey for naming and arrangement into sets, and to the latter gentleman for safe keeping until such time as means could be provided for their maintenance in Washington.

For the same reason as that just given, all the type specimens of insects which have been collected by the Institution have been divided among collaborators for study and arrangement, to be reclaimed at any time when required by the Institution. Nor is this system of co-operation confined to this country, for while through its exchanges the Institution holds friendly correspondence with all the principal scientific and literary establishments of the Old World, with a number of them it maintains relations of mutual co-operation in the way of affording assistance by sending rare specimens and furnishing required data in cases of special investigations.

While the result of the policy which has been adopted is the immediate advancement of knowledge, it tends incidentally to render the seat of government a center of scientific activity, which enlarges its reputation and extends its influence. Indeed, though Washington has generally been regarded as almost exclusively a focus of political agitation, it in reality contains a greater number of persons connected with scientific operations, and interested in intellectual pursuits, than any other city of equal population in this country. In illustration of this remark I need only mention the officers of the Engineer Department, of the Coast Survey, of the Light-house Board, of the Ordnance Bureau, of the army and the navy, of the Patent Office, and of the Agricultural Department; also the computors of the Nautical Almanac, the professors of the National Observatory, and those of three colleges, three medical schools, a law school, and of an institution for the deaf and dumb; besides the the directors and assistants of the asylum for the insane, two hospitals, and of the various bureaus of the government, the greater part of whom are men of more than ordinary culture, on many of whom the Institution can call for assistance and co-operation.

Publications.—The Smithsonian publications, as has been frequently stated before, are of three classes: the Contributions to Knowledge, the

Miscellaneous Collections, and the Annual Reports. The first consists of memoirs containing positive additions to science resting on original research, and which are principally the result of investigations to which the Institution has in some way rendered assistance. In all cases the memoirs are submitted to a commission for critical examination, and only accepted for publication on a favorable report. The Miscellaneous Collections are chiefly composed of works intended to facilitate the study of certain branches of natural history or of meteorology, and are designed especially to induce individuals to engage in studies as specialties, to which in leisure moments their thoughts may recur, and by observations and collections in relation to which they may not only contribute to their own pleasure but also advance the cause of science. The Annual Reports are published at the expense of the government, with the exception of the illustrations, which are furnished by the Institution. Up to the year 1854 these reports were published in a pamphlet form, and contained merely an account of the operations of the Institution for the year; but since that date an appendix has been added, principally consisting of translations, from foreign journals, of articles not accessible to the English reader, but of interest to our meteorological observers, and to persons generally who are interested in the progress of knowledge. With the addition of this appendix each report forms a volume of between 400 and 500 pages, bound in boards, with a cloth cover. The first volume of this series contains a reprint of all the previous reports of the Secretary, the will of Smithson, and the enactments of Congress in regard to the bequest, and hence in the full set of these reports a continuous history of the Institution is given from its organization to the present time. The whole number of volumes, including the present, is fifteen; of these it is to be regretted that the greater part of the extra numbers were destroyed in the fire of 1865. All the reports since 1862 have been stereotyped, and the plates of these have been preserved.

During the past year the 15th volume of the Smithsonian Contributions to Knowledge has been published, and, in conformity with the rules adopted, has been distributed to institutions in this country and abroad. The volume contains 604 pages, and is illustrated with 43 woodcuts and 17 plates. The several articles contained in this volume which were published separately, and an account of which was given in previous reports, are as follows:

1. An investigation of the Orbit of Neptune, with general tables of its motion, by Professor Simon Newcomb.

2. On the fresh-water glacial drift of the northwestern States, by Charles Whittlesey.

3. Geological researches in China, Mongolia, and Japan, during the years 1862 to 1865, by Raphael Pumpelly.

4. Physical observations in the Arctic seas, by Isaac I. Hayes, M. D.

Another publication during the year, which is intended to form a part

of the 16th volume of the Contributions, is entitled "Results of meteorological observations at Marietta, Ohio, between 1826 and 1859," by Dr. S. P. Hildreth. An account of this was given in the last report under the head of meteorology, and copies of it have been distributed to the meteorological observers. It contains 46 quarto pages, and is illustrated with 14 woodcuts.

Several parts of the miscellaneous collections have also been published. The first is a catalogue of the Orthoptera or upright winged insects of North America, described previous to 1867, prepared for the Smithsonian Institution by Samuel H. Scudder, of the Boston Society of Natural History. This work is intended as an index in which the student can find a reference to every published account of any species of Orthoptera found on the continent of North America or in the West Indies, together with the exact names given to the insects in the original descriptions. The publication and distribution of this list will assist the author himself in obtaining materials for a contemplated elaborate monograph on the same subject, while it will tend to advance science by calling attention to this interesting but heretofore little studied order of insects; an order which includes, however, among others, the cockroach and the grasshopper—the one so prejudicial to domestic comfort, and the other so often subversive of the hopes of the farmer. The preparation of this work is a gratuitous contribution by Mr. Scudder to the branch of natural history in which he is specially interested. It consists of 89 octavo pages, and will form a part of the eighth volume of miscellaneous collections.

The next publication of the year 1868 is a volume forming part four of a series of monographs of the Diptera, or two-winged insects of North America, by Baron R. Osten Sacken. Parts one and two of the same series previously published by the Institution were prepared by Dr. H. Loew, of Prussia, and the third part is in an advanced state of preparation by the same author. This volume contains the first part of a monograph of the North American *Tipulidæ*, the representative of which is known as the crane-fly, an insect whose larvæ are extremely destructive to crops of various kinds, devouring the roots of cereals and pasture grasses, and almost all the plants ordinarily cultivated in fields or gardens. The ground covered by the author in this monograph embraces all the known North American species, exclusive of those of the West Indies and Mexico. The principal areas from which the specimens described have been obtained are the environs of the cities of Washington and of New York, but the author also made collections during occasional excursions to different parts of New York, Pennsylvania, and New England, besides receiving contributions from other parts of this continent. Thus, as far as the more common species are concerned, the middle and northern States may be said to be tolerably well represented in this volume, the regions west of the Allegha-

nies and the British Provinces not so fully, while the country south of Washington is, in this respect, almost entirely unexplored. The author as well as the Institution is indebted to Mr. Samuel Powel, of Newport, Rhode Island, an amateur and patron of science, for the devotion of much time and practical skill to the preparation of magnified photographs of the wings, from which the illustrations presented on the steel plates were reduced. This volume contains 345 pages, illustrated with four plates and seven woodcuts.

Among the memoirs accepted for publication, and formerly described, is one by Dr. John Dean, giving the results of a series of microscopical investigations of the *medulla oblongata*. This paper was stereotyped and about to be published as a part of the 13th volume of the Contributions, when the expensive steel plates for its illustration were destroyed by the fire of 1865. Owing to the absence of Dr. Dean in Europe, a considerable delay has occurred in procuring a new set of these illustrations. The stereotype plates of the letter-press were, fortunately, preserved, and we are now ready to publish an edition of the memoir for distribution as a part of the 16th volume of the Contributions.

Since the last report an elaborate work founded principally on original research has been presented to the Institution, by Lewis H. Morgan, esq., of Rochester, New York. It is on the systems of relationship adopted by different races and tribes of men. About 20 years ago the author found in use among the Iroquois Indians, of the State of New York, a system for the designation and classification of family relationship of a singular character and wholly unlike any with which he was previously familiar. Under this system, for example, all the children of the several brothers and sisters of an individual are considered as his own children; all the brothers of his father are habitually regarded and addressed as his own father; all the sisters of his mother as his mother, &c. Mr. Morgan afterwards found the same system in use among other Indian nations, in which, while every term of relationship was radically different from the corresponding terms in the Iroquois, the classification was the same. Extending the research to other fields of inquiry, he found before the close of 1859 that the same system prevailed among the principal Indian nations east of the Rocky mountains, and that traces of it existed both in the Sandwich Islands and in south India. He therefore resolved to prosecute the investigation upon a still more comprehensive scale, and to attempt, if possible, to investigate the systems adopted by the different families of mankind. This, however, required a more extensive foreign correspondence than a private individual could hope successfully to maintain. He therefore made application to the different boards of foreign missions, and also to the Smithsonian Institution, for such co-operation in the furtherance of his object as it might be in their power to afford. The Institution accordingly issued circulars and schedules, which were distributed to its correspondents in all parts of the world. Through his own immediate labors and the assistance just mentioned,

the author has been able to construct tables of relationship of as many as 70 Indian nations, speaking as many independent dialects, and also tables of the systems of the principal nations of Europe and Asia, a portion of those of Africa, of Central and South America, and of the islands of the Pacific. The tabulated schedules will represent the systems of relationship of upwards of four-fifths of the entire human family.

The memoir presents in a brief form the following systems or methods of indicating the relations of consanguinity: 1st. That of the Aryan family, as typified by the Roman form. 2d. That of the Malayan family, as indicated by the Hawaiian mode. 3d. That of the American Indian family, as represented by the Seneca-Iroquois. According to the author's generalizations all these systems of consanguinity resolve themselves into two radically distinct forms, one of which he calls the descriptive and the other the classificatory form. The first assumes as its fundamental basis the antecedent existence of marriage between single pairs. Before it could have come into existence mankind must have made some advances in civilization; it follows the regular course of descent, describing each individual with reference to his parental derivation. In the second form the relation of cousanguinity is only given in classes, the same term of consanguinity being applied to a number of persons not standing in precisely the same proximity of actual relationship. This system, according to the author, seems to indicate that it was adopted in a state of society in which marriage between single pairs was unknown or exceptional. This memoir was first referred to a commission, consisting of Professor J. H. McIlvaine and Professor William Henry Green, of Princeton, New Jersey, who recommended its publication, but advised certain changes in the method of presenting the subject. After these modifications had been made it was submitted to the American Oriental Society and was by it referred to a special committee, consisting of Messrs. Hadley, Trumbull, and Whitney, who, having critically examined the memoir, reported that it contained a series of highly interesting facts which they believed the students of philology and ethnology, though they might not accept all the conclusions of the author, would welcome as valuable contributions to science.

Besides the foregoing the following papers have been accepted for publication and are now in the hands of the printer:

The Indians of Cape Flattery: by J. G. Swan; Investigation of the Path of a Meteoric Fire-ball: by Professor J. H. Coffin, of Lafayette College; Description of a part of a Mummy Case: by Dr. Charles Pickering; Land and Fresh-water Shells of North America: by W. G. Binney and Thos. Bland.

In addition to the foregoing the discussion and reduction of all the observations relative to the rainfall of the north American continent have been completed and will be published during 1869. The whole amount expended during the past year for publications was about $5,800.

A larger sum, however, will be required for this purpose during the present year.

The Smithsonian Institution is now in possession of a large amount of manuscript material relative to the natural history, geology, and ethnology of the whole of the northern part of the American continent, extending from Labrador to Behring's straits, and northward to the Arctic sea, including Greenland and the vicinity of Von Wrangell's land. These materials have been derived principally from special explorations, directed by the Smithsonian Institution, and with the co-operation to a greater or less extent of the Chicago Academy of Sciences. They have been gathered by the officers of the Hudson's Bay Company, at their stations in various parts of the northern portion of the continent, by the scientific corps of the Russian telegraph expedition, and by special explorers acting under the immediate auspices of the Institution. That part which relates to natural history is now nearly ready for the press, and will probably be published during the coming year, while that relative to physical geography is in an advanced stage of preparation. This includes all the scientific reports made to the Russian telegraph company by its employés, and liberally furnished, by the company or its officers, to the Institution. The material also contains a large number of vocabularies as well as other information relative to the languages of the country, which we hope soon to have in a proper state for publication. All these contributions, together with the observations of Kane, McClintock, and Hayes, which have been discussed and published by the Institution, form no small addition to the knowledge of the North American continent, and will forever remain a monument of the munificence and a memorial of the name of Smithson.

The annual report for the year 1867 was printed as usual by order of Congress, and the extra number of 10,000 copies ordered as heretofore. In addition to the report of the secretary, giving an account of the operations, expenditures, and condition of the Institution for the year, and the proceedings of the Board of Regents to May 2, 1868, it contains the following articles: biographical notices of Professor C. C. Jewett, formerly librarian of the Institution; of William Henry Harvey, of Dublin, author of an extensive work on Algæ, published by the Institution; memoirs of Legendre, Peltier, and Faraday; a sketch of the history of the Royal Institution of Great Britain; a memoir on the family Jussieu, and the natural method of classification in botany; the natural history of organized bodies; the electrical currents of the earth; considerations and facts relative to electricity; queries about expression for anthropological inquiry; the various modes of flight in relation to aeronautics; man as the cotemporary of the mammoth and reindeer in middle Europe; photo-chemistry; an account of the astronomical observations at Dorpat and Poulkova; traces of the early mental condition of man, account of Indian remains, ancient mounds, &c.; explorations in Central America and Lake Winnepeg; sketch of the flora of

Alaska; various letters on meteorology; prize questions of societies in Europe; and a list of abbreviations used in England at the present time. This publication is constantly growing in popularity, and, next to the report of the Agricultural Department, no document is in greater demand. We may mention, as a proof of this, that a considerable portion of the copies allowed the Institution for distribution among its own correspondents has been absorbed, during the last year, in meeting the applications of members of Congress for the supply of their constituents. In complying with these applications we have never failed to represent that a larger edition of the report is highly desirable for distribution, both by the Institution and Congress, and that an addition of 5,000 copies to the number which has been printed would cost comparatively but a trifle after the stereotype plates have been placed upon the cylinder of the printing press.

Explorations and collections in natural history.—From the first establishment of the Smithsonian Institution until the present time a considerable portion of its annual resources has been devoted to explorations for the development of the natural productions of North and Central America, particularly in relation to zoology, botany, and mineralogy. Of late years a number of other institutions have entered the same field, either independently or in co-operation with this Institution. Foremost among those which have made separate explorations is the great museum of comparative zoology at Cambridge, under the direction of Professor Agassiz. The late expedition of this renowned naturalist to South America has been crowned with a larger collection of specimens in zoology than has ever been obtained through the exertions of private enterprise. Among societies which have co-operated during the past year with the Smithsonian, and scarcely in a rank below any other in regard to zeal and efficiency, are the Chicago Academy of Science, the Boston Society of Natural History, and the Peabody Museum of American Archæology and Ethnology of Cambridge, Mass., as also the Kentucky University of Lexington. In giving an account of what has been done during the year under review in the line of natural history we shall adopt, as in previous reports, the geographical order.

In reference to *Arctic* America the contributions from Mr. Macfarlane and Mr. McDougal of the Mackenzie river district have added largely to the materials previously received from that region, and are of special interest in regard to Oölogy. The last invoice from Mr. Macfarlane is fully equal to those with which he has favored the Institution in previous years, and entitles him to the credit of being the largest contributor to the Smithsonian collections, and of having done more than any other person in making known the productions and character of the regions he has explored. The record of specimens bearing his name already amounts to over ten thousand entries, including some of the choicest contributions to natural history and ethnology. A collection of birds

and eggs, including some new species of the latter from west of Lake Winnipeg, has been received from Mr. Donald Gunn, and of insects and birds from the vicinity of Hudson's bay from Mr. James Lockhart and Mr. B. R. Ross, to both of whom acknowledgments for valuable services have been frequently rendered in previous reports.

Mr. W. H. Dall, who was mentioned in the last report as having succeeded Mr. Kennicott as chief of the natural history corps of the Russian telegraph expedition, remained after the abandonment of that enterprise to continue his explorations among the Indians and Esquimaux along the Yukon, and within the Arctic Circle, including the most northern part of our new possessions. He has just returned and brought with him a valuable collection of the natural productions, as well as illustrations of the ethnology of the regions he has visited. Mr. Dall visited Sitka with the telegraph expedition, in 1865, then went to the Aleutian islands, and afterwards to Plover bay, in Eastern Siberia. He spent the winter of 1866 in the vicinity of St. Michael's, Norton's sound; went the next spring, with a single companion, to Fort Yukon, near the headwaters of the river of the same name, and continued his explorations on either side of the Arctic Circle until September, when he returned to Norton's sound to report the result of his labors to the engineer-in-chief of the telegraphic expedition. But learning that the enterprise had been abandoned, he concluded to remain in the country and continue the exploration on his own account. In the prosecution of this purpose he left St. Michael's in October, and spent the following winter among the Indians and Esquimaux, in the region between the Yukon and Norton's sound. In the spring he descended the Yukon, and in July commenced his homeward journey. His collections are rich in birds, eggs, plants, smaller animals, fish, fossils, and especially in ethnological illustrations. He also made copious notes on the physical geography, geology, and meteorology of the country. The first winter—1866–'67—was very cold, the thermometer descending, near Nulato, as low as 68° below zero. The second was much warmer; rain fell almost every day, and, with the exception of one occasion, the thermometer ranged from 10° below to 8° or 10° above the freezing point. As if, however, to compensate for this, the spring was longer and colder than had been known for 16 previous years. The short summers are quite warm, no snow remaining on the ground. Rapidly growing vegetables are cultivated by the Russian traders, such as turnips, radishes, and lettuce. An attempt to grow potatoes failed at St. Michael's, although a similar experiment is said to have been successful at Fort Yukon. This part of the country is of no value in an agricultural point of view, but affords an abundance of rich furs. It is thickly wooded in the interior, principally with spruce, poplar, and willow. Mr. Dall was kindly entertained by the inhabitants, who, on all the coasts north of the Aleutian islands and on that of the Arctic sea, consist of Esquimaux, while the inhabitants of the interior are Indians.

The expenses of original outfit for making collections in natural history during the telegraphic expedition were defrayed by the joint contributions of this Institution and the Chicago Academy of Science. Subsequently the telegraphic company itself made liberal provisions for facilitating the same object, and for furthering, as far as compatible with the primary intention of the enterprise, the advance of science. The costs of the expedition of Mr. Dall, after he left the service of the telegraph company, were borne by himself, and the results generously presented as a contribution to the cause to which he has shown himself so ardently attached. The transportation of all the collections from the western coast devolved upon the Institution, and but for the generous assistance of the Pacific Mail Steamship Company, it would have called for a larger outlay than we could well have afforded. Since Mr. Dall's return he has occupied a room in the Smithsonian building, and has been engaged in arranging and labeling his specimens preparatory to the formation of a descriptive catalogue. While he has been occupied in this work the Boston Society of Natural History, as well as the Institution, has contributed to his support, with the understanding that the former is to have a portion of the duplicates set apart for distribution.

Other collections of interest have also been received from Alaska, viz: those made by Mr. Bischoff, at Kodiak; and by Dr. Minor, in various localities visited during the cruise of the Wayanda; others still, from Captain White, of the same steamer; also from Captain Howard and Mr. George Davidson, of the United States Coast Survey.

Western United States.—The Institution still continues to receive specimens from the Pacific coast, and frequent communications relative to the physical geography, meteorology, and ethnology of the country. During the past year among the more important collections from California was a series of nests and eggs from Dr. Canfield, of Monterey, and of birds and shells from Mr. R. E. C. Stearns. But the most important exploration undertaken since the date of the last report has been that under the direction of Mr. Clarence King, authorized by Congress for a geological survey of the 40th parallel of latitude, principally in Nevada and the western portion of Utah. The results of this exploration are especially important from the facts obtained relative to the physical geography and meteorology of the country. A base line in a north and south direction was measured by astronomical observations at the two extremities, and from this a net-work of triangles was extended over the region surveyed, by which the topography was determined and the materials furnished of an accurate map of a part of the country previously imperfectly known. The party consisted of four geologists, including Mr. King, four topographers, two botanists, one zoologist, and one meteorologist. All the specimens collected, filling 60 boxes, with the exception of those of botany, have been received at the Institution, and are now in process of being arranged for study and subsequent distribution. The botanical collections have been given in charge to Professor

Eaton, of Yale College, for the determination of the species and their relations to the flora of other portions of the United States, but will finally be sent to the Institution, to the care of which all specimens collected by government expeditions are assigned. In the same connection it may be mentioned that Dr. Hitz has continued his explorations on the upper Missouri, and contributed specimens of fossils, skins of birds, eggs, &c.

At the last session of Congress an appropriation was made for explorations under the direction of the Land Office. This survey, the conduct of which was consigned to Dr. F. V. Hayden, extended over the Black hills, Laramie plains, the headwaters of the Little and Big Laramie rivers to Bridger's pass. It also included a survey along the Pacific railroad from Fort Saunders to Green river. The report of this survey has been made to Joseph S. Wilson, esq., the Commissioner of the Land Office, with whom all the specimens collected have been deposited. Dr. Hayden, however, made an independent su vey under the auspices of the Institution, along the eastern base of the Rocky mountains to Denver city, and southward to the Sangre de Christo pass, across the San Luis Potosi park and the valley of the Rio Grande, and thence into New Mexico, returning northward through the Poncho pass, across the Arkansas into the South park, and through this into the mining regions of Colorado. Besides the geological notes which were made during this expedition, a large number of specimens was collected; and as no appropriation of Congress was made for the transportation of the latter, the cost has been defrayed by the Institution. The specimens have been received and are now awaiting their examination and final disposition. Another exploration which will be mentioned under the head of ethnology, was conducted by Dr. E. Palmer, in the Indian territory, the collections from which were but little less important as illustrative of natural history than of Indian life and ethnology. Dr. Palmer is now in the Institution assorting the specimens and preparing his notes for publication.

Middle and South America.—Colonel Grayson has been engaged in prosecuting his exploration in northwestern Mexico, and has furnished large collections of its ornithology. To him more than to any other may justly be ascribed, says Professor Baird, a knowledge of the species of birds of that region. Under the joint auspices of the Smithsonian Institution and the Kentucky University, at Lexington, Professor Sumichrast, a well-known naturalist long resident in Mexico, has gone to the Isthmus of Tehuantepec to make observations and collections in natural history, which will doubtless throw light upon the geographical distribution of species. Two boxes of specimens have just been received as the first fruits of this expedition. Dr. Sartorius has also continued his important contributions from Mirador. Explorations have been further prosecuted in Costa Rica, a region which has been the subject of much attention on the part of the Institution, and a valuable collection of specimens has been received from Mr. M. Calleja, made by himself and Mr. J. Zeledon, as

well as contributions from Dr. Von Frantzius, from Captain J. M. Dow, Mr. Henry Hague, Mr. George Latimer, Dr. Destruges, and other correspondents mentioned in the list of donors. A series of birds of the Galapagos islands has been presented by the Swedish Academy of Sciences through Professor Sundevall, furnishing us with the first illustrations of the fauna of that group, so remarkable for its land and marine animals. Mr. W. H. Hudson has continued to make collections of birds in the Argentine provinces, and Mr. Albuquerque and Dr. Smith have rendered the same service in regard to those of Brazil. Specimens from Peru have been received from Dr. Sclater, while Mr. Salvin has sent types of several new species from Veragua, on the isthmus of Panama.

Explorations and collections in ethnology.—During the past year greater effort has been made than ever before to collect specimens to illustrate the ethnology and archæology of the North American continent. This subject, it is true, has from the first been an object of interest to the Institution, as being a common ground on which the cultivators of science and of literature might harmoniously co-operate. It embraces not only the natural history and peculiarities of the different races of men as they now exist upon the globe, but also their affiliations, their changes in mental and moral development, and also the question of the geological epoch of the appearance of man upon the earth. So much interest has been awakened in the general subject, that Mr. George Peabody, with an enlightened liberality, has presented $150,000 to Harvard University, at Cambridge, for the foundation and maintenance of a museum and professorship of American ethnology and archæology, Although the funds of that establishment are not yet fully available. measures have been taken, under the direction of Professor Jeffries Wyman, to secure European specimens for comparison, and also to commence the collection of original records of the races of our continent. The Smithsonian Institution having inaugurated a number of special explorations, embracing ethnology as well as natural history, has invited the Peabody museum to co-operate in the enterprises, by contributing funds, with a view to sharing the results of the expeditions. This proposition has been favorably entertained, and an appropriation been made to assist an important exploration of ancient mounds in Kentucky, under the direction of Mr. Sidney S. Lyon. We cherish the hope that, as the funds of the Peabody museum become more and more available, our union of effort to extensively examine the monuments and collect all the relics, to illustrate as fully as possible the archæology and ethnology of the American continent, will be crowned with success.

The interest in the archæological remains of America is by no means confined to this country. They are considered of much importance in Europe in the way of comparison with those of the old world, and specimens have been diligently sought for by collectors from abroad. Mr. William Blackmore, of Liverpool, in particular, a gentleman of wealth

and intelligence who has founded an ethnological museum at Salisbury, has made several visits to this country for the purpose of obtaining additions to his collections. He has purchased of Dr. E. H. Davis, for a large sum of money, the archæological specimens described and figured in volume I of the Smithsonian Contributions to Knowledge. Though it may, perhaps, be a matter of regret that Congress did not make an appropriation for the purchase of these interesting specimens, it is still gratifying to the lovers of science, irrespective of nationality, that they will be perpetually preserved and rendered available for the advancement of ethnology. While we ourselves were not able to retain in this country the originals, we have procured a complete set of facsimiles in plaster, which, for general investigation, are nearly as valuable as those from which they were taken.

The Institution is indebted to Mr. Blackmore for a series of photographs of American Indians; a model of Stonehenge; a number of electrotype copies of ancient medals; and a copy of a work written by Thomas Inman, M. D., for private distribution, on "Ancient Faith embodied in Ancient Names." Mr. Blackmore is enthusiastically interested in ethnology, and devotes his spare time, as well as a large portion of his ample means, to the prosecution of the subject. The museum which he has founded and munificently endowed consists of specimens intended to illustrate the anthropology of every part of the world, and is freely opened to the public, either for casual visits or for critical study. An account of it will be given in the appendix of this report, under the head of ethnology. We have found in Mr. Blackmore an efficient and liberal collaborator, who evinces a disposition amply to repay, in returns of specimens and information, the contributions we may be able to make to the stores he has already accumulated. In his late visit to this country he thinks he has found specimens of the early drift period, or of the first indications of the works of man on the earth, not previously known to exist on this continent. The locality of these remains is about 50 miles from Fort Bridger, in Utah Territory, and will not be forgotten as a point of special interest in our explorations.

It is now generally known that, in times long anterior to the dawn of authentic history, the practice extensively prevailed of constructing human habitations upon wooden piles driven into the shallow water of lakes, remains of which have been found especially in Switzerland, but also in other countries. Upon these piles platforms were placed and habitations erected, not for temporary occupation, merely, but for prolonged residence. Of these archæological remains accounts have been given in previous reports, and during the past year arrangements have been made, through the exchanges of the Institution, to obtain specimens from the more important localities in which they are found.

The following is an account of the more important explorations and additions to the collections of the Institution which have been made

during the past year in the line of ethnology. The first in value is that already referred to as having been undertaken under the joint auspices of the Institution and the Peabody Museum, by Mr. S. S. Lyon, of Indiana. In this exploration a number of mounds in Kentucky were opened, and more than fifty perfect crania, with many imperfect ones, and a considerable number of skeletons, were procured. There were disinterred also about thirty vases more or less perfect, a large number of stone axes, hammers, ornaments, beads, bone awls, &c., the whole filling seven barrels and four boxes with extremely valuable material. The crania and bones were referred to Dr. Wyman for special investigation, who reports that they had been received, that he had nearly finished cleaning the skulls, which would require many repairs, but that he hoped to do justice to a collection which affords an opportunity never before equaled of examining the skulls of American aborigines. Mr. Lyon's exploration has also furnished a series of ancient implements as well as casts of footprints sculptured in the rocks. Imitations of this kind, which have been frequently found, were for a long time supposed to have been formed by the actual impressions of human feet when the rock was in a soft condition, but subsequent investigations have shown them to be undoubtedly sculptured imitations of footprints. They have occasionally been found in rocks containing pebbles, but in these cases the pebbles, instead of bearing evidence of having been pressed down into a plastic material by a human foot, show clearly that they have been cut by the tool of a workman.

Professor J. W. P. Jenks, of Middleboro', Massachusetts, who has for many years been collecting objects of ethnology, has, in a spirit of praiseworthy liberality, allowed the Institution to select any specimens it might desire from his extensive cabinet. From the same place, some choice objects have also been received from Mr. Sylvester, as well as an interesting stone mortar and a stone axe, respectively the gift of Mr. E. Shaw and Mr. U. Sampson. Mr. Gregory, of Marblehead, has furnished some desirable specimens from eastern Massachusetts, as have also Mr. Levi Cole, of Beverly, Dr. Palmer, of Ipswich, Mr. Blake, of Boston, Mr. Burr, Mrs. Bryant, Mr. Jas. T. Ames, &c. To Amherst College, through Professor Hitchcock, the Institution is indebted for a large number of stone implements from western Massachusetts and Connecticut. Explorations of ancient Indian graves were also made, with satisfactory results, near Hingham, Massachusetts, by Professor Baird, in conjunction with Dr. Brewer, Messrs. John Brewer, T. J. Bouve, F. Burr, Gerrish, and Wells.

To Dr. W. Wood, of East Windsor Hill, Connecticut, the Institution is under obligations for his diligent efforts to increase its archæological collections; a number of boxes have been received from him filled with articles illustrative of the primitive stone implements of Connecticut. Valued contributions from an adjacent locality have also been received from Mr. Andrus. Special contributions of implements previously col-

lected in Maine, New Brunswick, and Pennsylvania, were likewise made by Mr. Boardman, Dr. Todd, Mr. Blake, Mr. Haley, Mr. Leonard Peabody, Mr. Hollis, and Mr. J. Hamilton. From Colonel E. Jewett, of Utica, the Institution has received an extensive and choice collection of relics especially rich in pipes and ornaments, beads, amulets, &c., gathered principally in New York and adjacent States. Mr. Robert Howell, of Tioga county, New York, has made several interesting contributions in the same line, and others have been received from the same region at the hands of Mr. Stephen Forman and Mr. Jacob Stratton. Scarcely inferior in extent and variety to the collection of Mr. Jenks is one made by the late Hon. George M. Keim, of Reading, principally in central Pennsylvania, but also in Texas and Ohio. In this is found the first specimen of a choice flint hoe, similar to that described by Professor Rau, in the Smithsonian Report for 1863, a second specimen of which has just been received from Mr. Granville Turner, of Illinois. The collection of General Keim was presented to the Institution by his children as a memorial of their father, and a very large and choice cabinet of minerals has, we learn, been given by them to Lehigh University with a similar object. Specimens from western Pennsylvania have been received from Dr. Walker.

The principal donations from the vicinity of Washington have been made by Mr. O. N. Bryan, some of which are very choice; by Mr. J. W. Slagle, and Mr. Tyler. Specimens from the eastern shore of Virginia have been presented by Mr. C. R. Moore. Mr. W. H. Edwards, of West Virginia, has contributed a number of choice articles from the Kanawha river and elsewhere, some of them unique. Mr. E. A. Dayton, an esteemed correspondent of the Institution, in the course of an extended tour through Tennessee and Kentucky last year, took advantage of the occasion to gather collections, and awaken an interest in the subject which has resulted in large additions to our cabinet. Our attention having been called by Mr. Dayton to a remarkable stone idol found near the mouth of a cave at Strawberry Plains, Tennessee, a correspondence was entered into with its owner, Captain E. M. Grant, which resulted in its being sent to the Institution. The most important collection of ethnological material yet received, however, is that presented by Captain J. H. Devereux, of Cleveland, Ohio, embracing a large number of nearly every variety of ancient stone implements, principally of Tennessee and Ohio, among them specimens of pottery of very different patterns from those usually met with. Some of them are remarkable for smoothness of surface and symmetry of outline, as well as for the style of ornamentation. We have stated before that a series of casts of the principal objects described in the first volume of the Smithsonian Contributions to Knowledge had been purchased, and it may be mentioned in this connection that other articles described in the same volume are in possession of Mr. W. S. Vaux, of Philadelphia, who obtained them through the purchase of the valuable collection of Mr. James McBride, of Ohio, whose

cabinet was freely open for study to Squier and Davis. From Lieutenant Belden and Captain Mills, of the United States army, Drs. C. C. Gray and Matthews, fine collections of dresses and implements of existing tribes of Indians have been received. The most extensive series, however, of modern objects of this kind pertaining to the United States, and obtained during the year under review, is that gathered by Dr. Edward Palmer, in the Indian territory, including specimens relating to the Comanches, Kioways, and other neighboring tribes. The collection consists of war implements, such as bows, arrows, shields, battle-axes; hunting and fishing implements, such as hooks, spears, nets, &c.; a large variety of dresses, ornaments, including ear and finger rings, breast-plates, &c.; tobacco-pouches, pipes of various materials, bowls, spoons made of wood and horn, a variety of whips, articles used for gambling, including packs of cards made of skins, and bundles of sticks with which bets are decided, from the manner in which they fall when thrown upwards; also floor coverings made of parallel sticks attached by sinews; the whole forming very complete illustrations of the manners and customs of the tribes before mentioned.

Some of the most important additions of the year to the stone series were included in a collection presented by Dr. Yates, of California. This collection embraced, in addition to a number of characteristic implements of the natives of California, moulds of those found under the lava of Table mountain, and which formed the subject of an animated discussion at the meeting of the American Association in Chicago last summer. It is proposed to make casts from these moulds for distribution to the principal museums in this country and abroad. Extensive collections were made in Alaska, during the year, by Dr. T. T. Minor, surgeon of the United States steamer Wayanda, embracing stone articles of superior finish. Other objects, to which much value is attached, from the same region, have been received from Captain Howard and Captain J. W. White; and very extensive collections made by Mr. Dall are on their way. Mr. R. Macfarlane and Mr. Strachan Jones have furnished continuations of collections previously contributed, in articles relative to the Esquimaux of the northern coast of America. Thanks to the co-operation of the officers of the Hudson's Bay Company, among whom may be mentioned Messrs. Ross, Gaudet, Hardisty, and Kirkby, but especially Macfarlane, the Institution is in possession of what would appear to be a full representation of the life of the Esquimaux of that region, as illustrated by their dresses, weapons of war, their implements for fishing and the chase, household articles, ornaments, &c.

In this connection mention should not be omitted of a number of interesting stone implements contributed by Mrs. H. R. Schoolcraft, of Washington, the widow of the celebrated ethnologist, some of which are described in his elaborate work on the Indian tribes of North America. Among other articles for which the Institution is indebted to the liberality of Mrs. Schoolcraft is a cast of the inscription on Dighton Rock,

Massachusetts, sometimes supposed to be of Runic origin, but which, like the drawings on the same rock, are generally considered as having been made by the primitive Indian occupants of that region.

It will have been observed that nearly all the additions to the ethnological collections referred to, have been from the United States and British possessions. Very important donations have, however, been received from other parts of America. Captain J. M. Dow, of New York, has presented the Institution with a collection of ancient pottery, of stone images and implements from Nicaragua, Costa Rica, and Chiriqui, some of them of remarkable character. Other specimens of Chiriqui pottery were included in the collection of Colonel Jewett, already referred to. Mr. George A. Latimer, of Porto Rico, has presented remarkable stone implements of the ancient inhabitants of the West Indies, among which is a specimen in the shape of an ellipsoidal stone ring, not unlike a horse collar in form, though rather less in size, being about 15 inches in its largest diameter. It was possibly worn about the neck as a badge of office in public processions. From Captain Dow we have received another wrought stone in the form of a large inverted U. It is conjectured that it might have been placed across the neck of the victim when stretched on the altar of sacrifice.

The occasion here presents itself of stating that in a communication, through the Department of State, from Mr. de Cesnola, United States consul at Cyprus, we were informed that a remarkable discovery of Phœnician and Greek antiquities had lately been made in that island, and that two boxes of the specimens were in readiness to be transmitted to Washington as presents for the National Museum. On the receipt of this information a letter was addressed to the Secretary of the Navy, asking that, if not incompatible with the rules of the service, some United States vessel, being in the vicinity, might be authorized to stop at the island and procure the articles above designated. To this letter a prompt answer was received from the Navy Department, containing the information that orders in accordance with the request had been issued to the commander of the Mediterranean squadron. The following are some of the facts in regard to the discovery in question. In the month of December, 1867, a Greek laborer, digging for building-stone within the precincts of a little village called Galli, found a very old oven-shaped tomb, containing pieces of skulls and other bones, and also some curious colored vases. On examining the ground a few yards in circuit other tombs were found, indicating the existence of an ancient burial-site. The discovery was kept secret from the authorities of the place, but was disclosed to the foreign consuls on the island, by whom the search was prosecuted. The American consul, Mr. Cesnola, obtained from the Turkish government at Constantinople a firman allowing him to search for antiquities wherever he might desire. With this he succeeded in discovering the existence of a series of Phœnician tombs beneath the ancient Greek burial ground. These tombs, which were

oven-shaped, with the mouth closed by large stones, were six and a half feet below the level of the Greek interments, and from nine to eleven feet below the surface of the earth. The articles found in the graves and tombs were of gold, silver, precious stones, bronze, copper, glass, marble, and terra cotta. The whole collection numbered 2,310 pieces; the expense of the digging, $7,300 in gold, was defrayed by an association composed of the English, French, and American consuls, and an English banker. We need not say that the safe arrival of the portion of these relics intended by Mr. Cesnola for the Smithsonian Institution will be looked forward to with much interest.

But the explorations of the Institution in regard to ethnology have not been confined to the contents of mounds or to implements gathered from the surface of the ground, or brought to light by casual excavation. It is well known that in almost every part of the world contiguous to the sea there exist accumulations of shells collected into heaps or mounds. These mounds were long supposed to have been produced by natural causes, but comparatively recent investigations have shown that they are the remains of the festal or daily repasts of the ancient inhabitants. Thus their examination becomes an object of special interest; yet nothing had been done in this department of research in our own country until lately, when examinations were commenced by Professor Rau in New Jersey, Professor Wyman on the coasts of Florida, Maine, and Massachusetts, and by gentlemen connected with the Essex Institute, (now the Peabody Academy of Science,) in the vicinity of Salem, Massachusetts. During last summer, Professor Baird, of this Institution, after taking part in the Salem exploration, instituted an investigation as to the shell-heaps of the coast of New Brunswick. In this enterprise he received the voluntary assistance of Mr. G. A. Boardman, Dr. Todd, of St. Stephens, Mr. Josiah Simpson, of St. David's, and Dr. Parker, of St. Andrews. They examined several new depositories, which yielded unexpectedly large numbers of implements of horn, bone, and stone, together with the remains of the animals which had served as food. Of this exploration a full account will hereafter be prepared for publication in the report of the Institution.

Nor yet are lacustrian structures and shell heaps the only sources from which a knowledge of the manners and customs of pre-historic times may be acquired. The early inhabitants of almost every part of the world took advantage of natural caverns as places of shelter, and in these have left the indications of their former presence. An examination of the deposits of earth on the floors of these caverns, and sometimes even beneath the incrustations produced by the evaporation of the water charged with lime, which has dripped from the ceiling, have often disclosed the bones of men, and also artificial implements, mingled with the remains of extinct animals. A cave of this kind, in central Pennsylvania, was examined a number of years ago by Professor Baird, not with a view to the discovery of archæological remains, but those of the

animals which might have inhabited the cavern in previous geological periods. The débris which he obtained were carefully preserved, but not subjected to a critical examination. The Professor, however, has more recently resumed the investigation in the light which new facts have shed upon the connection of these caves and their contents with the character, the pursuits, and the condition of men in pre-historic times. An account of the result of these researches will also, in due time, be published.

The ethnological specimens we have mentioned are not considered as mere curiosities collected to excite the wonder of the illiterate, but as contributions to the materials from which it will be practicable to reconstruct by analogy and strict deduction the history of the past in its relation to the present. In the case of the remains of animals and plants, from which the geologist reconstructs the flora and fauna of ancient times, inferences are drawn from petrifactions, shells, bones and teeth. These, however, are not sufficient in the case of anthropology, and, in addition to the study of human skeletons and crania, recourse must be had to the relics of the works of the men of the past; to the remains of their houses, tombs, fortifications, temples, implements, and ornaments, in order to determine their relation to the races which now inhabit the earth. Ethnology, it must be admitted, is at present in an elementary condition: in the period through which all science must necessarily pass—that of the collection of material; and, consequently, the only deductions which can be drawn to-day are principally of a provisional character. It is true that the evidences in favor of the greater antiquity of the appearance of man on the surface of the earth than has been heretofore generally admitted have been accumulating from year to year, yet it can scarcely be said with fairness that the question is fully settled. Other hypotheses than those which have been advanced may be suggested to explain the facts observed. But, be this as it may, the investigation should be prosecuted without regard to preconceived views. We may rest satisfied that religion and true science cannot be at variance; the one properly understood, and the other rightly interpreted, must agree in final results. In short, we should follow the rule laid down by the Bishop of London in a lecture delivered at Edinburg, that: "The man of science should go on honestly, patiently, diffidently—observing and storing up his observations and carrying his reasonings unflinchingly to their legitimate conclusions, convinced that it would be treason to the majesty at once of science and of religion if he sought to help either by swerving ever so little from the straight line of truth." Care however must be taken that the provisional hypotheses of science are not mistaken for absolute truths, and premature attempts be made to explain discrepancies between the two great domains of thought, which, after all, may arise from partial views of the connection of phenomena.

Museum, and care of specimens.—The exhibition rooms, to which the public generally have admission, have been limited since the fire to the large hall on the first floor of the main building, and the apartment on the same floor in the southern projection, the latter containing ethnological specimens of a large size, principally from Central America, the former, the general collection brought home by the Wilkes Exploring Expedition, and the large additions since made to it by the several explorations under the direction of officers of the general government.

It is greatly to be regretted that in the original plan of the building proper attention had not been given to the purposes to which it was to be applied. The spacious room, in which the rich collections of ornithology and ethnology are contained, presents to the eye a succession of large pillars which obstruct the view of the cases containing the specimens, and it is only by a separate examination of the contents of these cases that the value of the collections can be duly estimated. In fitting up the room of corresponding dimensions in the second story, an opportunity will be afforded of adopting arrangements far better suited for a comprehensive display of the vast number of objects with which in time it will be furnished.

During the past year, in addition to the rooms before mentioned, the west connecting range has been provided with cases for which the Institution is indebted to the Commissioner of Patents, and to which will be transferred, in the course of a few weeks, the ethnological specimens from China and Japan, a part of which are still in the Patent Office. It is intended to devote the whole of this room to ethnological specimens, especially those illustrating the dress of the different inhabitants of North America. The west wing of the building, previously occupied by the library, is temporarily appropriated to the alcoholic specimens, and to such other collections as are not of special interest to the general public; it is used also for storing duplicates for distribution.

For the support of the museum during the last year Congress appropriated $4,000, while the actual expense of the care and preservation of the collections, independent of the interest on the cost of the building, was upwards of $10,000. If to this be added only $10,000 for the rent of the apartments, it will be seen that the cost of the museum to the Institution cannot be estimated at less than $20,000 per annum.

The steady increase in the receipt of specimens has been maintained, and has fully equalled in number and value that of any preceding year. The different additions were from 186 different parties, and were contained in 308 boxes, 149 bundles, 19 jars and cans, 2 kegs, and 7 casks; 485 in all, inclosing many thousand specimens, a detailed notice of which will be found in the appendix to this report. It should be remarked that all these specimens are not intended to swell the number exhibited in the national museum, but that only the type specimens of such as are not already in the collection are to be devoted to this purpose, and the remainder made up into sets for distribution.

From the large accessions of specimens received during the year, much labor has been required merely to unpack, arrange, and catalogue them. The great importance should be borne in mind of prompt action in regard to affixing some permanent mark to each article so as to presevre all the data necessary to render it of value as material for scientific research. The locality and date of capture of every object of natural history, the name of the collector and donor, its association in place with other objects, its sex and age, are all points which can rarely be learned from the specimen itself and must be immediately recorded. This is done by affixing an ineffaceable number to the specimen and making an entry corresponding to that number in a bound record book kept in a fire-proof room. Whenever a specimen admits of it, the items above mentioned are marked upon the object itself, but as long as the numbers and records are in existence the identity of the article can always be verified and the facts in regard to it ascertained. The determination of the exact name of the specimen at the time of entry is a secondary matter, as the specialist can at any time ascertain this point from the internal evidence; the other data. being entirely those of association, cannot be ascertained in the same way.

Special attention has been given to the large ethnological collections belonging to the Institution, and considerable progress been made towards their permanent arrangement. The smaller objects, such as pipes, carved bones, stone implements, &c., will be mounted as soon as practicable on suitable tablets; all the older articles have been washed with a solution of carbolic acid, to destroy the mould produced by the water with which the building was deluged at the time of the fire, and such of the new ones as are liable to attacks from insects have been impregnated with poison. Each object of the collection will have the name of the donor, locality, &c., placed upon it, and the whole series will be completely arranged for study and exhibition during the present year. The principal work in this branch has been done under the direction of Prof. Baird, by Dr. E. Foreman and Dr. E. Palmer.

Other objects that have received attention in the way of rearrangement and improvement are those of human and other crania, shells, mounted birds, nests and eggs, &c., in which labor Professor Baird has been assisted by Dr. T M. Brewer, Dr. William Stimpson, Dr. E. Foreman, Mr. W. H. Dall, Mr. Zeledon, and Mr. R. Ridgway.

Among the most interesting collections received from abroad, in return for specimens presented by the Institution, may be mentioned a series of minerals and rocks from the K. Ober-Berg Amt, of Breslau, and a skeleton of the moose of Europe, from the zoological museum, Copenhagen. The latter will furnish the means of comparing the European variety with the closely allied if not identical moose of northern America. Of the living animals received from different parts of this country, it will suffice to mention a golden eagle, from Professor H. Shimer; a number of menopomas from Dr. Walker; gopher turtles from Dr. Wilson; and a

Rocky mountain salamander from Mr. J. C. Brevoort. It will be recollected that the living animals of a larger size heretofore presented to the Institution have been transferred to the National Asylum for the Insane, under the care of Dr. Nichols.

Distribution of specimens.—The distribution of duplicate specimens to public museums and in exchange has been prosecuted as extensively during the year as was compatible with the large additions continually coming in and requiring immediate attention. The surplus material of plants, shells, minerals, and fossils has been, however, to a considerable extent, made up into sets, and supplied as far as they would go to the parties having the first claim. Other collections, however, will be ready for similar distribution as soon as the investigations connected with them and their arrangement into sets can be completed. The great amount of labor required for this will be evident when it is recollected that every specimen sent out is numbered and accompanied by a label giving the name, locality, and donor. Professor Baird, who has the special charge of this branch of the operations, has been assisted in his labors by a number of young gentlemen, who having been engaged during the summer in explorations, avail themselves in the winter season of the facilities of the library, the collections, and apartments furnished by the Institution to prepare their reports for publication. Those who are at present rendering service of the kind above mentioned are Messrs. Meek, Dall, Palmer, Zeledon, Bannister, and Ridgway.

Agreeably to the resolutions adopted by the Board of Regents at its last session, that "the distribution of specimens to foreign establishments, carried on by the Smithsonian Institution, be continued and extended, but that at the same time proper returns be required," we have applied to the leading foreign museums which have been favored by our contributions for desiderata especially needed in this country, and have the assurance that in due time valuable collections will be transmitted to us from all parts of the world.

Among the establishments to which application has thus been made and a favorable response received, are: The British Museum and Royal College of Surgeons, London; Archæological Museum, Zurich; Public Museum, Berne; Museum of Lausanne; Academy of Sciences, and Botanical Garden, St. Petersburg; Royal Museum, Lisbon; Ethnological Museum, Moscow; Ethnological Museum of University of Christiania; Zoological Museum, Copenhagen; Zoological Museum of University of Berlin; Academy of Sciences and National Museum of Antiquity, Stockholm; Imperial Geological Institute, Vienna; University of Chile; Philosophical Society, Leeds; Ethnological Museum, Paris; Melbourne Museum, Australia.

Investigations.—It has always been the policy of the Institution to furnish specimens for special study and investigation to naturalists of established reputation, either in this country or abroad. The use of these specimens is

granted under the express condition that they are to form the subject of investigation, the results of which are to be published by the Institution or some other establishment, and that in all cases full credit is to be given to the Institution for the assistance it has rendered. Furthermore, in the case of the preparation of a monograph, a full set of the type specimens, correctly labeled, is to be put aside for the National Museum, and the remainder of the specimens made up into sets for distribution. The following list presents the more important cases of the loan or assignment of materials during the past year. Some of the specimens have already been returned, while the remainder are still in the hands of the parties to whom they were intrusted:

Crania of the recent and fossil bison, musk ox, &c., to Professor L. Agassiz, of Cambridge, Mass.; land shells of Central and South America to Thomas Bland, of New York; land and fresh water shells of North America to W. G. Binney, Burlington, N. J.; nests and eggs of North American birds to Dr. T. M. Brewer, Boston; birds of South America and Alaska to John Cassin, Philadelphia; Alcadæ of North America to Dr. Elliott Coues, United States army; collections of American and foreign reptiles to Professor E. D. Cope, Philadelphia; fungi from the Indian territory to the Rev. M. A. Curtis, Hillsborough, N. C.; unfigured species of North American birds to D. G. Elliott, New York; diatomaceous earths and deep-sea soundings to Arthur M. Edwards, New York; Lepidoptera from various North American localities to W. H. Edwards, Coalburg, Va.; seeds of Boehmeria, received from the Department of Agriculture, to Dr. Earl Flint, Nicaragua; plants collected in Ecuador by the expedition under Professor Orton to Dr. Asa Gray, Cambridge; miscellaneous specimens of North American insects to Professor T. Glover, Department of Agriculture, Washington; general collection of birds of Costa Rica and Yucatan to George N. Lawrence, New York; American Unionidæ to Isaac Lea, Philadelphia; series of North American salamanders to St. George Mivart, London; American Diptera to Baron R. Ostensacken, New York; Lepidoptera of Ecuador and Yucatan to Tryon Reakirt, Philadelphia; plants collected in Alaska by various expeditions to Dr. J. T. Rothrock, McVeytown, Pa.; birds of Buenos Ayres, received from W. H. Hudson, and a series of small American owls, to Dr. P. L. Sclater and Osbert Salvin, London; miscellaneous collections of American Orthoptera to S. H. Scudder, Boston; collections of American Hemiptera to P. R. Uhler, Baltimore; American myriapods and spiders to Dr. H. C. Wood, Philadelphia; human crania from northwestern America and the ancient mounds of Kentucky, also collections from the ancient shell-heaps of Massachusetts and New Brunswick, to Dr. Jeffreys Wyman, Cambridge.

Few persons are aware of the great extent to which this Smithsonian material has been used by American and foreign naturalists, or the number of new facts and new species which have been contributed to natural history through its means. A complete bibliography of the titles

of the various books and memoirs containing in part or entire the results of these examinations, with lists of the new species, would form a large volume. Among the published results of the examination of the materials furnished by the Institution during the last year may be mentioned the following:

A monograph of the Alcadæ, by Dr. E. Coues, in the Proceedings of the Philadelphia Academy of Natural Sciences; various herpetological papers in the same Proceedings, by Professor E. D. Cope; portions of various fasciculi of his work on North American birds, by D. G. Elliott; monograph of the North American Lepidoptera, by W. H. Edwards; catalogue of the birds of Costa Rica in the museum of the Smithsonian Institution, and some special papers in the annals of the New York Lyceum of Natural History and the Proceedings of the Philadelphia Academy, by George N. Lawrence; paper on the Unionidæ in Proceedings Philadelphia Academy, by Isaac Lea; monograph of the North American Diptera, Part IV, by Baron R. Ostensacken, published by the Smithsonian Institution; catalogue of Alaskan plants in the Report of the Smithsonian Institution for 1867, by Dr. J. T. Rothrock; list of birds sent from Buenos Ayres to the Smithsonian Institution, and other papers, in the Proceedings of the Zoological Society of London, by Dr. P. L. Sclater and O. Salvin; "on crania of Tschuktchi and Esquimaux tribes," by Professor J. Wyman, in the Proceedings of the Boston Society of Natural History. In all these cases full credit is given for the aid which has been afforded by the Institution.

The Secretary, during the past year, has given a large amount of thought and labor to investigations relative to light and sound as aids to navigation, in connection with his duty as one of the members of the United States Light-house Board. He has also, in his connection with the National Academy of Sciences, devoted nearly all his time, for the space of two months, to investigations relative to the proper form of meters for gauging the quantity of proof spirits produced by distilleries, in order to determine the amount of tax to be paid to the government.

Professor Baird has continued his investigations relative to the birds of North America, especially those of Alaska, the result of which has been the addition of fifteen species to those previously known to exist in this country. He has also edited a report by Dr. Cooper on the birds of California, for the geological survey of that State under Professor J. D. Whitney, and is now engaged in the preparation of a new manual of the ornithology of the United States. This work, which is to be illustrated by numerous engravings on wood, will be published by Little & Brown, of Boston, in the course of next year.

Exchanges.—The cost of the international system of exchanges in the transportation of books and specimens is constantly increasing, and now forms no inconsiderable part of the annual expenditures. Were it not for the liberality of various companies, we should be unable to con-

tinue the system, at least in its present dimensions; and we embrace this occasion again to express acknowledgments for the efficient aid thus rendered to the cause of science and to the promotion of kindly feeling between the United States and the other nations of the world. The following are the companies to which special thanks are due, namely, The Pacific Mail Steamship Company, North German Lloyd. Hamburg American Steamship Company, General Transatlantic Steamship Company, Pacific Steam Navigation Company, Inman Steamship Company, Cunard Steamship Company, California and Mexico Steamship Company, and Panama Railroad Company. To this list must be added several other lines which have granted similar facilities during the past year, namely, the Mexican Steamship Company, Union Pacific Railroad, United States and Brazil Steamship Company, North German Lloyd, (Baltimore line,) and the Atlantic Mail Steamship Company.

Acknowledgments are also due for favors rendered in connection with foreign exchanges to E. J. Davison, esq., Argentine consul; José I. Sanchez, esq., consul of Venezuela; Señor B. Blanco, consul-general of Guatemala; L. H. J. d'Aguiar, consul-general of Brazil; R. C. Burlage, consul-general of Netherlands; Hon. E. Gutierez, minister from Costa Rica; to the American Board of Commissioners of Foreign Missions; Real Sociedad Economica, Havana; Board of Foreign Missions, New York; American Colonization Society, Washington; Society of Geography and Statistics, Mexico; University of Chili; Bataviaasche Genootschap, Java; Institute of History, Geography, and Ethnology, of Rio Janeiro.

The Institution frequently receives applications from foreign governments and societies for official publications of the States or general government relative to certain branches of political economy, statistics, education, &c. During the last year a request of this kind was received from the Belgian government, desiring us to procure all the publications of the States in regard to public schools. In answer to our circular asking for these documents, a large and valuable collection was received, for which the thanks of the Institution were returned to the following persons, namely: to A. Rogers, second auditor of Virginia; T. Jordan, secretary of state, Pennsylvania; S. C. Jackson, assistant secretary Board of Education, Massachusetts; J. A. Morris, school commissioner, Ohio; N. Bateman, superintendent education, Illinois; C. J. Hoadley, state librarian, Connecticut; F. Rodman, secretary of state, Missouri; R. A. Barker, secretary of state, Kansas; Ed. Wright, secretary of state, Iowa; C. W. Wright, secretary of state, Delaware; J. E. Tenney, secretary of state, Michigan; and the secretary of state, Wisconsin.

Another application of a similar character was received from the government of Norway for the publications of the United States relative to military affairs, which, on being referred to the heads of departments and bureaus, secured a large number of the desired publications. Acknowledgments for these favors are due to General E. D. Townsend, adjutant general; General A. A. Humphreys, chief engineer United

States army; Surgeon General Barnes; Paymaster General Brice; General Dyer, chief of ordnance; Commodore Jenkins, chief of bureau of ordnance and hydrography, Navy Department; General Myer, chief signal officer.

For official co-operation with the Institution in its various plans for the promotion of knowledge and important assistance rendered, besides the foregoing, we may mention Hon. William H. Seward, Secretary of State; Hon. Hugh McCulloch, Secretary of the Treasury; Hon. Horace Capron, Commissioner of Agriculture; General Meigs, Quartermaster General; Mr. Spofford, librarian of Congress; Professor J. H. C. Coffin, superintendent Nautical Almanac; and Commodore Sands, of the National Observatory.

In 1867 a proposition was made to the Institution by the librarian of Congress relative to establishing and conducting a system of exchange of official documents between the government of the United States and those of other nations. In accordance with this, a circular was addressed to the different governments having relations with the United States for the purpose of ascertaining their views as to such an exchange. In every case the proposition was regarded with favor, and at the ensuing session of Congress an act was passed directing that 50 full sets of all documents published at the Government Printing Office should be set apart for the purpose in question, and appropriating a sufficient sum to defray the necessary expenses. Unfortunately, however, Congress neglected to direct the public printer to strike off the necessary copies for this purpose, in addition to the regular number previously required for the use of the government, and it was not until recently that the necessary legislation was procured to remedy this omission. As soon as the printing of the documents of the present session of Congress is completed, the exchange proposed will be initiated. In anticipation of the receipt of the annual supply of the documents of our government, several large packages containing documents of foreign countries have been already received.

At the commencement of the system of international exchanges, great delay and considerable expense were incurred in consequence of custom-house requirements and tariff duties, but as the importance of the system became more evident, and the reputation of the Institution better established, one government after another consented to the entrance of packages without examination and free of all restrictions, until at the present time there is no exception to this practice.

The first effort towards the establishment of this desirable condition of free intercourse was made in 1852, through Sir Henry Bulwer, then minister from Great Britain to the United States. Through his recommendations the British authorities at first permitted the entry of such books from the Institution intended as presents to learned bodies as might be recommended for that privilege by the Royal Society of London. This, though an important concession, was still attended with consider-

able delay, and on further solicitation the rule was so relaxed that at present the Smithsonian agent finds no difficulty in obtaining the passage of the packages at a mere nominal charge through the custom-house. With the precedent of the British authorities the Institution experienced no difficulty in making a satisfactory arrangement with the French officers of customs. Packages for Germany and central Europe, addressed to our agent, Dr. Flugel, are entered at Bremen or Hamburg, then transferred to the Leipsic custom-house, from which they are released on the formal application of the agent to the authorities of the Zolverein. Parcels for Belgium and Holland are entered at Amsterdam, which is a free port. Those for Italy are entered at Genoa, which is also a port of free entry. In all cases of transmission of packages an invoice of the contents is sent to the agent, which serves as the basis of his application for remission of duties and charges.

Library.—The works which have been received from all parts of the world in return for the Smithsonian publications, after being recorded at the Institution, have been transferred to the national library in accordance with the rules given in former reports. They are there under the care of an accomplished librarian and a corps of able assistants, accessible to all persons who desire to consult them, during every weekday of the whole year, with the exception of a month in summer. The transfer of the library of the Institution still continues to be approved by all who have attentively considered the advantages it affords to the Institution, the government and the public. It has relieved the Smithson fund of a serious burden in the cost of binding and cataloguing the books, in the pay of a librarian and his assistants, and in the expense of the maintenance of a separate establishment. It has enriched the library of Congress with a class of valuable works which could scarcely be procured by purchase, and it has facilitated the use of the books by collecting them in one locality, under the same system, readily accessible to the public. Some special works required for immediate use are still occasionally purchased, and besides these a working library is retained at the Institution, principally, however, of duplicate volumes, while such series as are needed for special investigation are brought back for the purpose. The care of these and the cost of those purchased make up the small expenditure given in the report of the executive committee under the head of the library.

The Library of Congress, or, as we think it should now be denominated, the "National Library," contains about 180,000 volumes, exclusive of unbound pamphlets and periodicals, and is rapidly increasing, the accessions during the year ending December 1, 1868, according to the report of Mr. Spofford, the librarian, amounting to 8,498. This library is emphatically a library of progress, for while it continues to increase by purchase in its own series of standard works of all times, its additions, through the contributions to it of the Institution, include the trans-

actions of the principal learned societies of the world, or the works which mark more definitely than any other publications the actual advance of the age in higher civilization.

An idea has, in some cases, been entertained abroad that the Institution, since the transfer of the library, no longer desires to receive books, but measures have been taken to counteract this impression and to assure Societies and other correspondents that no change in this respect has taken place in the policy of the Institution, and that books on all subjects are still desired both for its own collections and for presentation to other establishments in this country.

The following is a statement of the books, maps, and charts received by exchange in 1868:

Volumes:		
Octavo	1,316	
Quarto	394	
Folio	60	
		1,770
Parts of volumes and pamphlets:		
Octavo	2,565	
Quarto	761	
Folio	279	
		3,605
Maps and charts		134
Total receipts		5,509

The following are some of the larger donations received in 1868:

From the Royal Northern University, Christiania, 24 volumes and 27 pamphlets.

The Royal Society of Northern Antiquaries, Copenhagen, 9 volumes and 8 pamphlets.

The Imperial Academy of Sciences, St. Petersburg, 25 volumes and 27 pamphlets.

From His Majesty the King of Prussia, "Kunstdenkmäler des christlichen Mittelalter in den Rheinlanden," 1st part, vol. iii. "Preussen's Schlösser und Residenzen, von A. Duncker," vol. ix, and "Scriptores Rerum Prussicarum," vol, iii; all in continuation of works previously sent.

The Hungarian Academy of Sciences, Pesth, 51 volumes and 178 pamphlets.

The Ducal Library, Oldenburg, 34 volumes, consisting of a series of state calendars and other statistical works.

From J. G. Cotta, Augsburg, 11 volumes:

From H. De Saussure, Geneva, 10 volumes and 13 pamphlets:

From the Chamber of Commerce, Bordeaux, 7 volumes:

The Société Imp. des Sciences, de l'Agriculture et des Arts, Lille, 12 volumes of "Memoires:"

The Société d'encouragement pour l'Industrie Nationale, Paris, 14 volumes "Bulletin:"

The Société Imperiale et Centrale d'Agriculture, Paris, 26 volumes "Memoires," 12 volumes "Bulletin."

From the Museum de Douai, 11 volumes and 15 pamphlets: consisting principally of transactions and proceedings of societies.

National Library, Madrid, 12 volumes and 15 pamphlets.

The Meteorological Office, London, 6 volumes, 37 pamphlets, and 16 charts.

The Hydrographic Office, London, 6 volumes, 10 pamphlets, and 43 charts, giving the results of the latest maritime surveys.

From the National Library of Greece, Athens, 112 volumes and 39 pamphlets, principally on the philosophy and literature of ancient Greece.

Thomason College of Civil Engineering, Rourkee, 13 volumes and 44 pamphlets.

Royal Asiatic Society (North China branch) Shanghai, 4 volumes "Journal."

Library of Parliament, Melbourne, 10 volumes and 14 pamphlets.

Real Sociedad Economica de la Habana, 630 volumes, 13 pamphlets, and 1 chart.

University and Government of Chili, Santiago, 58 volumes, 13 pamphlets, and 30 charts.

Massachusetts State Library, 11 volumes.

Ohio State Library, 10 volumes.

Vermont State Library, 11 volumes.

But, perhaps one of the most interesting contributions is a work relative to history and philology published in folio parts of fac-similes of the national manuscripts of England, presented by Right Honorable the Secretary of State for War. These fac-similes are executed with minute precision as to accuracy, by the photozincographic process, under the direction of Colonel H. James of the ordnance department. The series includes documents belonging to each reign, from William the Conqueror to Queen Anne, arranged chronologically so as to illustrate the changes in the handwriting, and the language of different periods of English history. A translation is given of each document into modern English, together with a short account of its history. The first volume extends from William the Conqueror to Henry VII, and includes autographs of each sovereign, beginning with that of Richard II, and of many princes, prelates and nobles, whose names have become famous in history. Among the number are a series during the reign of Richard III, and several from the king himself.

The second part is made up of fac-similes selected from the public records of the reigns of Henry VIII and Edward VI. Among them are holograph letters, and autographs of Henry VIII, Queen Catharine of Aragon, Cardinal Wolsey, the Emperor Charles V, Anne Boleyn, Archbishop Cranmer, Queen Catharine Parr, Ann of Cleves, &c. The

third part contains fac-similes of state papers, royal letters, and other documents, both public and private, belonging to the reigns of Queen Mary and Queen Elizabeth. Among those of the former are autographs of her Majesty and of her cousin and rival, Lady Jane Grey, holographs and autographs of King Henry the Second, of France, the King of Hungary Cosmo de Medici, the Lady Elizabeth of England, Thomas Gresham, Roger Ascham, &c. Among those of the reign of Queen Elizabeth, besides those from herself, are letters of Mary Queen of Scots and her husband Bothwell, and of the most distinguished nobles of Scotland; of John Knox, Sir Humphrey Gilbert, James VI of Scotland, Sir Francis Vere, Sir Walter Raleigh, and other celebrated personages. The exaggerated terms of courtesy which were in use among eminent personages at that period are illustrated by several examples in this volume. The publication of the fac-similes of these valuable and interesting documents is to be continued, and we learn from the preface that similar fac-similes of the national manuscripts of Scotland have been undertaken, and those of Ireland recommended.

It may be proper to recall the fact that the library of Smithson, or so much of it as was received by the Institution, with his personal effects, was not destroyed by the fire, and has been placed in a suitable case for permanent preservation.

Mr. Theodore Gill, who was formerly assistant in the library of the Institution, has been appointed one of the principal assistants in the national library, but he still continues his investigations in natural history at the Institution, and acts as the intermediate agent between the two establishments. Miss Jane Turner, who vindicates by her accuracy and efficiency the propriety of employing her sex in some of the departments of government, still continues to register the books as they are received through the extended system of international exchange.

Gallery of Art.—The original act of Congress organizing the Institution directed that, in addition to the support of a museum, library, &c., provision should also be made for a gallery of art. In compliance with this direction a commencement was made by the purchase of a series of valuable engravings, illustrative of the progress of the art from the earliest times, and also a series of Indian portraits was received on deposit. With these and a number of plaster casts of distinguished individuals, principally donations, a collection of articles was formed to which the name of a gallery of art was given. The Indian portraits, which had been deposited by the author, Mr. Stanley, together with a series of portraits also of Indians, belonging to the government, were destroyed by the fire. Fortunately the engravings, with few exceptions, were saved, and are now deposited with the books in the library of Congress. It was evident, however, that the proportion of the Smithson fund which could be devoted to the purchase of specimens of art worthy of preservation in a public gallery at the seat of government was far too small to do anything of importance in this line. It was therefore with

gratification that the Regents learned that a citizen of Washington, William W. Corcoran, esq., with an enlightened liberality, commensurate only with his means, had resolved to found an institution exclusively devoted to art. This design, which would otherwise have long since been fully carried out, was interrupted by the war. The large building which Mr. Corcoran had erected for the purpose was found necessary by the government for the use of the Quartermaster General and is still retained in possession of that officer. As soon as possession of it is restored to Mr. Corcoran, which it is believed will be done in the course of the present year, it, together with a liberal endowment equal in amount to the original fund of Smithson, will be given in charge to a board of trustees, who will immediately proceed to carry out the views of the generous founder. In accordance with the policy which the Institution has adopted in regard to the library of Congress, the Agricultural Department, and the Army Medical Museum, it will probably be considered advisable to enter also into friendly co-operation with this new establishment, and instead of attempting to support a separate gallery of art to turn over to it the articles which have already been collected, and thereby increase the space in the Smithsonian building for articles of natural history and ethnology.

Meteorology.—It was stated in the last report that with the diminished expenditure on the building, and the larger amount which could be appropriated to the active operations of the Institution, the reduction and discussion of the meteorological material which had been collected for 20 years would be resumed, and that we had commenced upon the rain-fall of the North American continent. Observations relative to this subject from upwards of 1,200 localities were placed in the hands of the computers. This work has been completed under the direction of Mr. Charles A. Schott, and will be put to press as soon as the illustrations are engraved. We are confident it will be considered by all who are competent to properly estimate its value, as one of the most important additions to the climatology of North America and the agricultural interests of the community which has ever been made. The same computers are now engaged upon the large amount of material relative to temperature, but the reduction and discussion of these will require more time than that which has been devoted to the rain-fall. It is estimated, however, that at the rate at which the work is now going on, it will be completed in the course of the next year.

The discussion of all the observations relative to the winds has been resumed under the direction of Professor J. H. Coffin, of Lafayette College, Pennsylvania, and will be prosecuted with as much rapidity as the nature of the subject, and the assistance afforded him, will permit.

All the more important meteorological observations which have been collected at the Institution during the last 20 years, are now in process of reduction, and when completed and the results published, we think

they will fully justify the expenditure of the Smithson fund which has been devoted to this subject.

The importance of a thorough knowledge of the climate of a country in relation to the well-being of the inhabitants can scarcely be overestimated. The character of the animal and vegetable productions of any part of the world mainly depends on the climate, and if, as in geological periods, we suppose this in any case to undergo a change, we are certain, from the operation of general laws, that the fauna and flora of the region will undergo a corresponding change. It is true that civilized man has in a degree, through science, the power of resisting the influence of climate to which his race has not been long subjected, yet if sufficient time be allowed for the weather to produce its effect, marked peculiarities of physical constitution and even mental characteristics will eventually be produced, though these will be somewhat modified by the artificial conditions which have been introduced. Even a difference in the degree of moisture of the atmosphere has been shown by a critical observer to induce marked changes in the manners and customs of Europeans in their emigration to this country.

The average temperature and moisture of each region, as well as the periodical fluctuations to which these elements are subjected, are essential data on which to base the choice of special objects of culture and to estimate the probable results as to success or failure in a given number of years. It is a fact to which the statesman and the intelligent farmer cannot be too much alive, that the great material prosperity of this country in the past has been due to the large quantity of fertilizing material originally in the soil, and that this has been exhausted to a far greater extent than is generally supposed. It is well known that the same soil which in the eastern States originally yielded 30, and in some cases 40 or 50 bushels of wheat to an acre, now produces but eight or ten. From a late estimate by the Commissioner of Agriculture the average yield of the whole United States is less than 12 bushels, while that of Great Britain is 28; the great excess of the latter over the former must be mainly due to the improved methods of agriculture. Indeed with the large extent of virgin soil in this country, producing spontaneously rich harvests, with the expenditure of a minimum amount of labor, we have had comparatively little necessity to adopt methods of scientific agriculture, but we have now arrived at the condition in which every year a new demand will be made for the application of knowledge and skill of this kind, and for all the light which can be shed upon the subject by meteorology, chemistry, physiology, and other branches of science.

It will be remembered that the meteorological system of the Smithsonian Institution was in a considerable degree interrupted, particularly in the southern States, on account of the late war. We have, however, during the past year succeeded in obtaining a number of copies of registers which were continued with but little interruption through the whole

period of the disturbance, and have also supplied a deficiency occasioned by the loss of the registers of 1860 in the fire which occurred at the Institution in 1865. For the purpose of exhibiting the extent of the material in possession of the Institution, and to give credit to the faithful and persevering observers who have so long gratuitously furnished contributions to this branch of science, there is given in the appendix to this report a full list of all the observers and of all the stations where records have been made from the beginning of the year 1849 to the end of 1868. The whole number of observers at present reporting to the Institution is about 400; of these 74 are furnished with full sets of instruments. The number of observers under the direction of the army is upwards of 100, of whom 50 are supplied with standard barometers and other compared instruments. With this combined system, interspersed with full sets of standard instruments, trustworthy data is obtained for determining the general climatology of the country. It is true that many of the instruments in use are not as perfect as could be desired, yet they serve to indicate differences in the elements, and thus afford the data for tracing the progress, as it were, of waves of atmospheric pressure, and also of waves of changes in atmospheric temperature.

Anticipating the important benefits which may result to our system of meteorological observations, particularly to those which relate to the prediction of storms on the Atlantic coast, we look forward with much interest to the completion of the Pacific railway. A well equipped physical observatory placed at the highest point of the road, namely, "Sherman's station," is very desirable, and we think it probable that assistance from the railway company may be obtained to establish and support an observatory of this character.

During the past year a large number of rain gauges of a simple form, such as were mentioned in the last report, have been procured and distributed to observers in various parts of the country. This gauge consists of a hollow cylinder of tinned iron 2½ inches in diameter, and 12 inches in height, coated inside and out with varnish to prevent rusting. The depth of rain is measured by inserting a graduated scale into the gauge, and noting the height to which it has been wetted, in tenths and parts of tenths of an inch. The quantity of water in a fall of snow is measured by melting a column equal in diameter to that of the gauge. This is obtained by pressing the gauge, mouth downward, through the snow to the ground and isolating the contents by passing under the mouth of the gauge a thin plate of metal. A rain gauge of this form, after an experience of many years, is found to give the most satisfactory results when used by ordinary observers.

The discussion of all the material which we have collected in regard to rain-fall, has served to point out the parts of the country in which the registration is most deficient, and exertions have especially been made to obtain observations from the great plains of the west and at the base of the Rocky mountains. The great current of the return trade wind,

which continually flows through the higher regions of the atmosphere over the whole United States and which at intervals reaches the surface of the earth, deposits its moisture, obtained from the Pacific, on the Sierra Nevada and other chains of the Rocky Mountain system, and thus gives rise to the arid basins and woodless plains of the western portion of our domain. A part, however, of this region may be rendered arable by means of irrigation, or, in other words, a portion of the precipitated vapor may be, as it were, reclaimed for agricultural purposes, by artificial means; and in determining the available resources of the country it is important that the amount of water, either in the liquid state or in the form of snow, which is precipitated in the mountains, should at least be approximately determined, and hence we have directed special inquiries to this point, supplying rain-gauges in all cases of explorations and giving definite directions as to ascertaining the depth of snow, the gauging of streams, &c.

Much has been written on the subject of reclaiming arid wastes by planting trees, but the facts which have been collected in regard to this matter are frequently misinterpreted, and the result of much research in reference to it misapplied. It should be recollected that trees cannot grow without moisture and that they have no power within themselves to create this essential element of their existence. It is true that in some cases where moisture exists but is retained in an aeriform condition by the radiating character of the soil, or carried away by the wind, it may be precipitated and rendered applicable to the uses of agriculture by the judicious planting of trees; while it is equally true that there are other localities in which the necessary water for vegetation can never be procured by artificial means. The necessary data for the investigation of this question in relation to the western portion of the great valley of the Mississippi can only be obtained by extensive series of observations on the relative humidity and the direction of the moisture-bearing winds of different portions of the country.

During the past year a self-registering barometrical apparatus, invented by Professor George W. Hough, of the Dudley Observatory, has been erected in the Institution, but owing to the position in which it was first placed the series of records has not been continuous, though from the records which have been obtained it would appear that the instrument is capable of giving valuable results. This instrument consists of an iron tube in the form of a siphon closed at the upper end and filled with mercury, and two cylinders or drums moved by clock work, to the surface of which is attached the paper receiving the register. On the surface of the mercury, in the shorter leg of the siphon, is an ivory float, fastened by a fine thread to one end of a lever, the other end of which terminates between two points connecting the opposite poles of a galvanic battery. As soon as the mercury begins to rise and while it continues to ascend, the end of the lever is pressed against the upper point, thus completing the circuit of an electro-magnet, which unlocks

the printing part of the machine, and a record is made in the form of an ascending curve on the drums and on a slip of paper in figures, on the principle of the printing telegraph. When the mercury falls the motion of the pencil is reversed by bringing into operation a second electro-magnet by which is traced a descending curve. Two drums are used, one giving the curve for two weeks and the other the same more developed for two days, the one serving as a check on the other. An interesting series of observations furnished from the United States engineer depot at Willett's Point, New York, by General Abbot, exhibits the almost perfect parallelism of two curves for nearly a month, one by an apparatus similar to this at Albany and the other at Willett's Point, from observations with an ordinary standard barometer, the distance between these places being upwards of a hundred and fifty miles. The parallelism of these curves exhibits not only the probable accuracy of the self-recording apparatus, but also the extent in a north and south direction of a wave of atmospheric pressure. The great improvement in meteorological data must depend in future on the introduction of self-recording instruments, especially at important points.

Beside the contributions made directly from the ordinary observations of the Institution, the following is an acccount of a memoir belonging to meteorology, previously noticed under the head of publications:

On the evening of July 20, 1860, a meteoric fire-ball passed over the northern parts of the United States and the adjacent parts of Canada, of so extraordinary a brilliancy as to attract the attention of numerous observers along its entire visible track of nearly 1,300 miles. The phenomenon was of so interesting a character that the Smithsonian Institution made exertions to collect observations in regard to it from its meteorological observers and other correspondents, which, together with accounts from newspapers and other sources, were placed in the hands of Professor Coffin, of Lafayette College, for the determination of the orbit of the meteor. In order to correct the observations, in cases where instruments could not be obtained, Professor Coffin directed that estimates should be made of the position of the meteor, by means of an extemporaneous quadrant, consisting of a graduated paper attached to a board, from an angle of which a small plumb-line was su•pended. The edge of this instrument being directed to the place in the heavens where the meteor was seen at its greatest elevation, gave approximately the angle of altitude. The meteor was first observed moving from a point over the western shore of Lake Michigan, though it is not improbable that it became luminous when it was somewhat further west, as the sky in that region was obscured by clouds, and it was not until it had reached a point 150 miles further east that the first reliable observation of its position was made; from this point many eyes watched its course, until it disappeared out at sea, in a southeasterly direction, beyond the island of Nantucket. Whatever may have been the orbit of this meteor before it became visible, it is obvious that the portion of the path that

was subject to observation was so near the earth as to be controlled almost entirely by its attraction, and not sensibly perturbed by other bodies. The orbit therefore ascertained, is not the path of the meteor in space, but that having the center of the earth in one of its foci. Professor Coffin proceeded with the data at his command, to determine the path upon the assumption that the earth was a sphere 7,912 miles in diameter, not taking into account its spheroidal form, nor the difference between the true and the apparent zenith. In prosecuting the investigations, the method adopted was as follows: The parallax and position of the meteor were obtained by combining in pairs observations taken on or near the same vertical plane. Unfortunately, the number of pairs of reliable observations was too few for much accuracy. An approximate orbit was, however, determined, from which azimuths and altitudes were deduced, and these compared with those given by the observations. The form of the orbit was then altered so as to diminish the discrepancies, and it was not until over fifty changes of this kind had been made that the final result was attained. The velocity per second, relative to the earth's center, which best corresponded with observations, was nine and three-fourths miles. The first approximate orbit satisfied the most reliable observations west of about longitude 76° or 77°; but further east the discrepancies were so great that they could be reconciled only by a sudden change in the curvature of the path, one at the point just named, and another two or three degrees further east. In the vicinity of the former of these points a remarkable rupture in the body of the meteor was observed, where it separated into two parts that appeared nearly of equal size, thus affording a rational explanation of the change in the elements. That a change should take place at a point of explosion was not difficult to understand, but the fact that the meteor descended quite rapidly towards the earth, until it reached the meridian of 74°, and afterwards rose, was difficult to comprehend. The most plausible explanation was suggested by Professor Lyman, viz: that the change in direction was due to the increased resistance of the air as the meteor descended into a denser portion. An attempt was made to deduce the quantity of the change from this hypothesis; the result, however, was not entirely satisfactory, an empirical change being assumed in the path near longitude 74°. An orbit was computed, the path of the meteor divided itself into three sections, the first and last of indefinite length, through only a small portion of which the meteor was visible; the other an intermediate portion of 160 miles in length, where it was most brilliant. The most important omission in the calculation of the elements of this meteor, according to Professor Coffin himself, was that of the spheroidal form of the earth, which became of importance in comparison with the small height of the meteor; but with the hope that the subject might hereafter receive at the hands of others a more thorough discussion, he concluded to slightly modify the elements, so as to afford an unperturbed orbit that would differ so

little from the disturbed one, that the azimuths and the altitudes which he had already computed for the one might serve for the other. The velocity of the meteor, when nearest the earth, was 9.76 miles per second; its least distance from the surface of the earth was 39.19 miles, at about the middle of New York.

Correspondence.—As the collaborators of the Institution generally reside at a distance, the business with them is principally carried on by mail. The same is also the case in regard to all the exchanges, and consequently the record of nearly all the transactions of the Institution is contained in the correspondence. Besides those relating to official business, hundreds of letters are received during the year, containing inquiries relative to the various subjects on which the writers desire information. If these cannot be immediately answered without much research, they are referred to collaborators who are experts in the various branches of knowledge, and who can readily supply information in regard to subjects within the range of their special studies.

In addition to the foregoing it may also be mentioned that there are four hundred meteorological observers, from each of whom several letters are received annually. The correspondence of the Institution being of such importance, it has been considered necessary to adopt a system in regard to it, which consists in registering in a book prepared for the purpose, every letter received which pertains to the business of the Institution. The mail is opened every morning by an assistant, who assigns to each letter a number, gives a synopsis of its contents, and notes to whom it is referred for answer. The letters are afterwards bound in volumes and indexed. Press copies are kept of all the answers. An idea may be formed of the amount of labor bestowed upon this branch of operations, when it is mentioned that the number of letters registered during 1868 was 5,141. This does not include letters acknowledging the receipt of donations from the Institution, which would swell the number of actual receipts by the mail to upwards of 10,000.

During the past year references of inquiries above referred to have been made to the following gentlemen: Dr. Torrey, of New York; Professors Gray and Wyman, of Cambridge; Dr. Leidy and Mr. Isaac Lea, of Philadelphia; Professors Whitney, Brush, and Newton, of New Haven; Drs. Woodward, Otis and Craig, of the Surgeon General's office; Prof. Schaeffer and Mr. W. B. Taylor, of the Patent Office; Professor S. Newcomb, of the Naval Observatory; and Mr. George Gibbs and Mr. J. H. Lane, of Washington.

Grounds.—The Smithsonian building, as is well known to the visitors of Washington, stands in the midst of a park, adorned with a collection of the principal ornamental trees which are susceptible of cultivation in this climate. This forms part of a reservation of the government denominated the "Mall," extending from the Capitol to the Potomac,

which, in accordance with the design of Mr. Downing, was to be entirely devoted to an extensive park.

This plan has been revived by the present Commissioner of Public Buildings, General Michler, of the United States army, who strongly advocates an appropriation for carrying it into execution. On the grounds adjoining the Institution to the west, also a part of the proposed park, within the last year a spacious building has been erected for the uses of the Department of Agriculture, and designs have been made under the present Commissioner, General Capron, for the establishment of an extensive arboretum. With the renewed interest which has been excited on this subject, and the rapid advance of the city in wealth and population, we doubt not the original plan will soon be realized. In the mean time, however, we would call attention to the fact that many of the valuable trees originally planted by Downing are being injured by the luxuriant growth and consequent crowding of those too near each other. Though the visitors to the Institution—and the number of these is by no means small in the course of a year, and from every part of the world—are delighted with the general appearance of the grounds and the picturesque effect of the building, yet their sense of propriety is shocked and their olfactory nerves outraged, in approaching the building from the city, by having to cross that most disgusting object known as the "canal," though for years it has done no service of any value in that capacity. It is, in fact, a Stygian pool, from which are constantly ascending in bubbles, as from a caldron, mephitic vapors. That part of it which bounds the Smithsonian grounds and those of the Agricultural Department, on the north, consists of a basin 150 feet wide, extending from Seventh street to Fourteenth street. Into this is poured most of the excrementitious matter of the city, which is suffered to decompose into offensive gases, and exposes with each ebb of the tide a mass of the most offensive matter conceivable. This subject, at the last session of the Board of Regents, was referred to the executive committee, who have given it special attention, and prepared a report which will be presented to the Board at the present session, and should be ordered to be published.*

The only reason assigned for suffering this nuisance to remain so long unabated is the difficulty of settling upon a plan of remedying the evil, but surely this need not longer to stand in the way since there is engineering ability enough in the country to solve problems of greater intricacy than the one under consideration. The only effectual cure of the evil is, in my opinion, to fill up the present basin, and construct a covered sewer of sufficient capacity to receive that part of the drainage of the city which cannot be turned in other directions. A wide street with concave surface to discharge very rare freshets, would afford a series of building lots of sufficient value to pay the

* This report will be found in the journal of proceedings of the Board of Regents in this volume.

expense of the improvement, while the value of property south of the canal would be greatly enhanced.

Before concluding this sketch of the history of the operations of the Institution for the year 1868, it becomes my duty to mention the death of Mr. William B. Randolph, who for many years has acted as book-keeper for the Institution, posting and auditing its accounts, and who for 60 years had been connected with the Treasury Department of the government. He was a gentleman of extensive information, a graduate of Princeton College, of inflexible integrity, esteemed and beloved by all who knew him. His life was prolonged with vigor of intellect beyond the usual term of earthly existence, and he died on the 15th of May last at the age of 81.

Since the death of Mr. Randolph the entire charge of the accounts has been given to the chief clerk, Mr. William J. Rhees, by whom they are prepared for quarterly examination by General Delafield and Dr. Parker, of the executive committee.

In conclusion, from all the facts which have been given in this report, as well as in previous ones, we think it may reasonably be claimed that the administration of the Smithson fund, on the whole, has been successful. Though the Institution has been subjected to loss by casualties, and has been exposed to adverse conditions during the most troublous times in the history of the nation, yet it has continued noiselessly and unostentatiously to extend its influence and benefits not only to every part of this country, but to all portions of the civilized world. This success, if mainly due to the definiteness of conception in the original plan, must, in no small degree, be attributed to the fact that the Chief Justice of the United States is the head of the Board of Regents, whose permanence of office, aside from other considerations, could not fail to secure, as has been conspicuously evinced in the case of both Judge Taney and Judge Chase, a warm and intelligent interest in the affairs of the Institution. Neither is it possible to overlook, in this connection, the favorable influence of the policy which, from the first, has invested in a single officer, the Secretary, the executive charge of the operations, thus confiding to him their conduct and rendering him responsible for their results, without in a single case interfering with his acts. Moreover, simple justice would require that due credit should be given to the capable and zealous assistants whom the Secretary has associated with himself in carrying on the multifarious and arduous duties of his office.

Respectfully submitted.

JOSEPH HENRY.

WASHINGTON, D. C., *January*, 1869.

APPENDIX TO THE REPORT OF THE SECRETARY.

Table showing the entries in the record books of the Smithsonian Museum in 1866, 1867, and 1868.

Class.	1866.	1867.	1868.
Skeletons and skulls	7,100	7,500	8,150
Mammals	8,685	8,900	9,300
Birds	45,000	50,000	54,000
Reptiles	6,582	7,150	7,200
Fishes	5,591	5,625	5,625
Eggs of birds	10,400	13,300	14,100
Crustaceans	1,287	1,287	1,287
Mollusks	18,500	18,500	18,500
Radiates	2,725	2,725	2,725
Annelids	110	110	110
Fossils	5,920	6,600	7,200
Minerals	4,941	5,150	6,625
Ethnological specimens	2,260	5,400	7,400
Plants	....	175	175
Total	119,101	132,322	142,400

The total number of entries during the year thus amounts to about 10,000; of which 4,000 are of birds, 2,000 of ethnological objects, 800 of eggs, &c.

Approximate table of distribution of duplicate specimens, to the end of 1868.

	Distribution to end of 1867.		Distribution in 1868.		Total.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skulls and skeletons	105	105	24	58	129	163
Mammals	808	1,588	44	79	852	1,667
Birds	9,437	14,579	571	861	10,008	15,440
Reptiles	1,662	2,715	37	107	1,699	2,822
Fishes	2,424	5,200	....	....	2,424	5,200
Eggs of birds	3,887	10,101	264	526	4,151	10,627
Shells	71,764	169,866	1,206	2,606	72,970	172,472
Radiates	551	727	....	....	551	727
Crustaceans	1,013	2,516	....	....	1,013	2,516
Marine invertebrates	1,838	5,152	....	....	1,838	5,152
Plants and packages of seeds	13,358	18,703	300	515	13,658	19,218
Fossils	3,361	8,927	40	75	3,401	9,002
Minerals and rocks	1,718	6,059	400	595	2,118	6,654
Ethnology	1,048	1,048	59	59	1,107	1,107
Insects	1,190	1,937	230	650	1,420	2,587
Diatomaceous earth	....	....	15	555	15	555
Total	114,164	249,223	3,190	6,686	117,354	255,909

Additions to the collections of the Smithsonian Institution in 1868.

Adams, Dr. A.—Nest and egg of white-winged crossbill, New Brunswick.
Adams, W. H.—Arrow-head, Illinois.
Agnew, Samuel A.—Fossils and Indian relics, Mississippi.
Albuquerque, Frederick.—Two boxes of birds and mammals, Brazil.
Ames, James T.—Beads, &c., from Indian graves, Lake Superior and Massachusetts.
Andross, W.—Indian relics from Connecticut.
Arnold, Benjamin W.—Phalangidæ and myriapods, Kentucky.
Baggett, J. B.—Box of novaculite and associated minerals, Arkansas.
Baird, Prof. S. F.—Stone implements, worked bones, shells, and bones of vertebrates, from ancient shell-heaps in New Brunswick and Massachusetts; bones from cave near Carlisle, Pennsylvania.
Barnes.—(See Surgeon General.)
Bauermeister, W.—Box of minerals, Indiana.
Belden, Lieutenant, U. S. A—Box Indian objects, Wyoming Territory.
Berendt, Dr.—Bottle of reptiles and nest of caterpillar, from Mexico and Guatemala; earth eaten by Indians of Mexico.
Berthoud, Dr. E. L.—Box human bones and fragments of mastodon, Colorado Territory.
Bischoff, Ferd.—General collections from Japan, East Siberia, Gulf of California, and Alaska.
Blackmore, W.—Collection of electrotypes of ancient British coins and medals; model of Stonehenge.
Blake, Charles.—Stone axe, Massachusetts.
Bliss, L. W.—Three skulls of mound builders, Wisconsin.
Boardman, G. A.—Indian relics, ancient Indian anchor, skins of birds and mammals, and birds' eggs from Maine, and bird skins from Florida.
Bolles, Rev. E. C.—Box of diatomaceous earth, Maine.
Bowman, J. B.—Two pieces marble, one of ash-wood, from Ashland, Kentucky.
Brewer, John.—Relics from ancient shell-beds and Indian graves, at Hingham, Massachusetts.
British Museum.—One can of fishes from Zanzibar.
Brown, Dr. G. H.—One box petrified wood, jasper, agate, &c., from the West Indies.
Bryan, O. N.—Indian pottery and stone implements, Maryland.
Bryant, Mrs. E. B.—Indian relics, Massachusetts.
Burr, Fearing.—Brass trinkets from modern Indian graves, Massachusetts.
Burroughs, J.—*Geothlypis philadelphia* and eggs, New York.
Calleja, Manuel L.—Box of birds, Costa Rica.
Canfield, Dr. C. A.—Two boxes specimens of natural history from California.
Carmichael, Daniel.—Stone implements, Maine.
Christ, Richard.—Stone axes, arrows, &c., Pennsylvania.
Cole, Levi.—Stone sinker and arrows, Massachusetts.
Coole, J. M.—Specimens of corundum and emery, Pennsylvania.
Cope, Prof. E. D.—One can of the fresh-water fishes of Virginia; one box miocene shells, Maryland; one can alcoholic specimens.
Corbin, N. J.—One lamprey eel and one snake, District of Columbia.
Curtis, Dr. M. A.—Field mice in alcohol.
Dall, W. H.—General zoological and other collections, Youkon river, Alaska Territory.
Davidson, George, United States Coast Survey.—One box geological specimens, two cans shells, and one lot of botanical specimens, and specimens of woods, Alaska Territory.
Davis, Henry.—Package shells, myriapods, &c., Iowa.

Davis, Dr. E. H.—Casts of North American antiquities, types of figures in "ancient monuments of Mississippi valley."
Davison, C. E.—Lepidoptera in alcohol, Michigan.
Dayton, E. A.—Indian implements, pottery, bones, and minerals, Tennessee.
Destruges, Dr. A.—Box of bird skins, reptiles, &c., in alcohol, South America.
Devereux, J. H.—Three boxes Indian relics from mounds in Tennessee, Ohio, &c.
Donahoe, Thomas.—Pileated woodpecker *(Hyl. pileatus)* in the flesh.
Dole, E. T.—Insects from Ohio.
Dow, Captain J. M.—*Tapirus Bairdii*, and other specimens in alcohol, minerals and fossils, insects, of Central America; antiquities from Costa Rica and Chiriqui.
Earle, W. H.—*Mallotus* in clay nodule, Ottawa river, Canada.
Eaton, Frank.—Indian stone relics, Pennsylvania.
Edwards, Dr. W. H.—Two boxes of fossil coal plants, Indian relics, &c., West Virginia.
Ellsworth, Mr.—Stone implements and marine animals, Massachusetts.
Engelmann, Dr. George.—Series of *Junceæ*, (American.)
Feltz, George B.—Stone hoe, Massachusetts.
Fenton, Elisha.—Minerals and Indian relics, Pennsylvania.
Fernald, C. J.—Ancient pipe, Aroostook county, Maine.
Fink, Hugo.—Specimens of wood of Mexican trees.
Fitski, Edward.—Silver quartz, Zellerfield, Hanover.
Flint, Dr. Earl.—Collection of plants from Nicaragua.
Forte, A. E.—Box of insects, Lake Superior.
Frolich, Jacob, jr.—One inferior maxillary bone, (human,) Arkansas.
Gerrish, Noah W.—Indian relics, Massachusetts.
Giraud, J. P.—Type of *Icterus Audubonii*, Texas.
Glover, Prof. T.—Bone of bear, horns of spike buck, Florida; African tattooing apparatus, Indian arrow-heads.
Gordon, T. W.—Mole cricket, Ohio..
Grant, Captain E. M.—Stone idol from Tennessee.
Gray, Dr. C. C., and Dr. Mathews.—One box Indian curiosities from Montana Territory.
Grayson, Colonel A. J.—Three boxes birds, &c., Mazatlan, Mexico.
Gregory, J. J. H.—Indian relics, Massachusetts.
Grinnan, A. G.—Bottle of reptiles and Indian relics, Virginia.
Gruber, F.—One box birds, California.
Gunn, Donald.—Two boxes birds' eggs from west of Lake Winnipeg; zoological specimens, Hudson's Bay territory.
Hackenburg, Dr. G. P., United States army.—Baculite, Mauvaise Terres.
Hague, Henry.—Alcoholic collections and specimens of natural history, Guatemala.
Hagemann, G. A.—Cryolite, &c., Greenland.
Haley, Mr.—Stone axe from Maine.
Hamilton, James.—Stone chisel, Pennsylvania.
Hammond, Phillip.—Lower jaw of a porpoise, Massachusetts.
Hathaway, Gideon P.—Large Indian pestle, Massachusetts.
Haymond, Dr. Rufus.—Box Indian relics from Indiana.
Hawkins, Samuel.—Sharks' teeth, Mississippi.
Hazzard, G. W.—Sulphuret of iron, Pennsylvania.
Hielscher, Thomas—Three bottles insects, minerals, &c., Minnesota.
Hitchcock, Prof. Edward.—Indian relics from New England.
Hitz, R. B.—Collections of specimens of natural history, geology, and ethnology, Dakota and Montana.
Hoover, Harry.—Minerals and Indian relics, Pennsylvania.
Hopkins, Prof. W. H.—Newly-formed sandstone, New York.

Horan, Henry.—Skin and skeleton of Madagascar rabbit, and skull of goat.
Howard, Captain W. A., U. S. R. M.—Two skeletons of the sea otter, one skin of sea otter, (young,) and ethnological collections, Aleutian islands.
Howell, R.—Indian relics, southern New York.
Hudson, W. H.—Box of bird skins, Buenos Ayres.
Ives, Frank.—Specimen of orthoceratite.
Imperial Botanic Garden, St. Petersburg.—Two boxes of plants, Russian empire.
James, Prof. Charles A.—Living horned frog.
Jeffries, J. B.—One box titaniferous ore, Virginia.
Jenks, Prof. J. W. P.—Large collection of Indian relics, Massachusetts.
Jewett, Charles.—Recent marine shells, coast of Maine.
Jewett, Colonel E.—Collection of Florida shells, Indian relics, New York, New Jersey, &c.
Jones, Prof. C. M.—Geological and zoological collections, Connecticut.
Keenan, T. J. R.—Insects, fossils, and Indian relics, Mississippi.
Keim, the late Hon. George W., through his children.—Three boxes Indian relics, Pennsylvania.
King, Clarence.—Fifty boxes of general collections, made in Nevada and Utah, during United States geological survey of 40th parallel.
Larkin, E. P.—Birds, &c., in alcohol.
Latimer, George.—Six jars alcoholic specimens, and one oval stone ring, West Indies.
Lawrence, George N.—Three species of humming birds, South America.
Lineeum, Dr. G.—Zoological specimens and fossils, from Texas, &c
Lincoln, Benjamin.—Box Indian relics, Maine.
Limpert, W. R.—One box birds' eggs, and two bird skins, Ohio.
Lockett, S. H.—Minerals and fossils, Louisiana.
Lockhart, James.—Insects, &c., of Hudson's bay.
Logan, Thomas M.—Skull of Digger Indian, California.
Lowe, Abram.—Relics from ancient shell heaps and Indian graves, Massachusetts.
Lyon, Sidney S.—Seven barrels and four boxes of bones of mound builders, and relics from mounds in Kentucky.
McComas, Dr. I. Lee.—Skin of *Lepus americanus*, (white,) two goshawks, and skull of red fox, from Maryland.
McCulloch, Hon. H., Secretary of the Treasury, United States.—Specimens of coal from Cook's inlet, Alaska Territory.
McDougal, J.—Two boxes birds' eggs, Youkon river.
McFarlane, R.—Sixteen boxes, eleven packages, and one keg of specimens of natural history and ethnology, Mackenzie River district, Hudson Bay territory.
Maloney, H. D.—Indian relics, Tennessee.
Merritt, J. C.—Indian arrows, Long island.
Mills, Major W. H.—Bow, arrows, and equipment of Apache Indians.
Minor, Dr. Thomas T.—Two boxes minerals, animals, and ethnological specimens, Alaska Territory; drawings made by Winnebago Indians.
Moore, C. R.—Indian relics, and skin of *Jaculus hudsonicus*, Virginia.
Nelson, W.—Fulgora, and large grasshopper and sea snake, Panama.
Orton, Prof.—Box of plants, Venezuela; can of alcoholic fishes, South America.
Palmer, Dr. Edward.—Ten boxes specimens of natural history and ethnology, Kansas and Indian territory.
Palmer, Dr. Charles.—Stone gouge and axe, Massachusetts.
Parker, Dr. N.—Bones from ancient shell heaps in New Brunswick.
Payne, Dr.—Box of minerals.
Peabody, Leonard.—Indian relics from Maine.
Pearsall, R. F.—Nest and eggs of *Empidonax traillii*, New York.
Peyton, Robert E., M. D.—Micaceous ore of iron, Virginia.
Pollis, Mr.—Slate spear, Maine.

Powell, Prof.—Two boxes birds, Colorado.
Reeve, J. F.—Collection of bird skins, South America.
Reid, Peter.—Box of flint arrow-heads, New York.
Reinhardt, Dr. J.—Skeleton of *Cervus alces*, Scandinavia.
Rice, Louis V.—Fossils from Lake Huron.
Rodifer, Jacob.—Minerals from Virginia.
Ross, A. C.—Indian relics and elephant's tooth, Zanesville, Ohio.
Ross, B. R.—Specimens of *Bernicla leucopsis*, and other birds, fossils, &c., Hudson's Bay territory.
Salvin, O.—Four birds, and box of eggs, Central America.
Sampson, Uriah.—Stone gouge, Massachusetts.
Sargent, Daniel.—One box flamingo eggs, from the Bahamas.
Sartorius, Dr.—Collection of birds and alcoholic specimens, Mexico.
Schoolcraft, Mrs. M. H.—Indian relics, axes, arrow-heads, &c., and plaster casts of inscription on Dighton rock.
Schott, Dr. A.—Botanical and zoological collections, Yucatan.
Sellman, Dr. J.—Sharks' teeth, Mississippi.
Seagrave, O. B.—One snake and two lepediptera, Florida.
Shaw, Eben.—Stone mortar, Middleboro', Massachusetts.
Sheppard, Lewis.—One milk snake.
Sherwood, Andrew.—One box of rocks and fossils from Pennsylvania.
Shimer, Prof. Henry.—Living golden eagle, from northern Illinois; bird skins from Illinois.
Slagel, J. W.—Indian stone axe and other relics, and miocene fossils, from Maryland.
Smith, Dr. J. B.—Box of birds, Bahia, Brazil.
Spencer, Dr. L. B.—Stalagmite from Virginia.
Starke, Mr.—Insects, shells, minerals, &c., Venezuela.
Stearns, R. E. C.—Collection of shells, California.
Steele, G.—Indian relics, California.
Stinson, Captain James.—Tertiary shells, New Brunswick.
Stone, J. M.—Fossil shells, Illinois.
Stratton, Thomas.—Two packages minerals, &c., Mt. Baker, Washington Territory.
Stratton, L.—Indian relics from New York.
Sumichrast, Dr.—Zoological collections, Orizaba, Mexico.
Sundevall, Prof. C. J., Stockholm.—Birds of St. Bartholomew and Galapagos islands, (for Academy of Sciences.)
Surgeon General United States Army.—Minerals, &c., Upper Missouri; box of minerals collected by Dr. B. B. Miles, United States army.
Sylvester, S. H.—Indian relics, Massachusetts.
Talen, Rev. V.—Specimen of granite used in Mormon temple, Salt Lake City; also photograph of the building.
Thaxter, L. L.—*Turdus swainsoni* and *pallasi*, Massachusetts.
Thomas, M., & Sons.—A complete skeleton, and separate head of Irish fossil elk.
Thompson, Rev. D.—Box fossils and Indian relics, Ohio.
Thompson, Mrs. J.—Cane carved by Nisqually Indians.
Todd, Dr. W. H.—Relics from ancient shell beds in New Brunswick.
Tolman, Mr.—One box birds' eggs, Illinois.
Tyler, Samuel.—Indian stone axe, Prince George county, Maryland
Ullrich, Lewis.—One specimen garfish, and two boxes lepidoptera, Ohio.
University of St. Thomas, Costa Rica, Prof. Lucien Platt.—Two boxes minerals, &c.
Van Patten, Dr. C. H.—Two mammals, Guatemala.
Von Frantzius, Dr. A.—Birds, mammals, &c., from Costa Rica.
Wakefield, Dr. E. St. George.—Skin of Arkansas siskin, Arispe.

Walker, R. L.—Specimens of living menopoma, and one box Indian relics, one living tortoise, and other collections, Pennsylvania.
Walter, William.—Twenty-five bird skins, District of Columbia.
Wilcox, H. B.—Fresh-water shells, Michigan.
Wilkes, Admiral Charles.—Two stone axes, Gaston county, North Carolina.
Wilson, Dr. S. W.—Living gophers, *(Testudo polyphemus,)* Georgia.
Wise, H. G.—Cock's spurs, New York.
Wood, Dr. William.—Indian relics, Connecticut.
Wright, Charles.—One box land shells, fishes, insects, &c., from Cuba.
Wyman, Professor J.—Humerus of *Alca impennis*, from shell heap, in Maine.
Yates, Dr. L. G.—Natural history and archælogical specimens, California, &c.

LITERARY AND SCIENTIFIC EXCHANGES.

Table showing the statistics of the Smithsonian exchanges in 1868.

Agent and country.	Number of addresses.	Number of packages.	Number of boxes.	Bulk of boxes in cubic feet.	Weight of boxes in pounds.
Dr. Felix Flugel, Leipsic:					
Russia	52	88	......	....	....
Germany	370	441	......	....	....
Switzerland	38	51	......	....	....
Total	460	580	36	378	10,821
Royal Swedish Society of Sciences, Stockholm:					
Sweden	12	29	2	21	650
Royal University, Christiania:					
Norway	8	17	2	21	650
Royal Danish Society of Sciences, Copenhagen:					
Iceland	1	2	......	....	....
Denmark	14	25	......	....	....
Total	15	27	2	21	650
Frederic Muller, Amsterdam:					
Holland	50	78	......	....	....
Belgium	26	39	......	....	....
Total	76	117	6	63	1,950
G. Bossange, Paris:					
France	147	185	......	....	....
Spain	8	11	......	....	....
Portugal	4	6	......	....	....
Total	159	191	15	157	4,875
R. Instituto Lombardo, Milan:					
Italy	81	91	5	53	1,625
W. Wesley, London:					
Great Britain and Ireland	219	317	22	231	7,150
Rest of the world	99	177	14	112	2,800
Grand Total	1,129	1,557	104	1,057	31,171

Packages received by the Smithsonian Institution from parties in America, for foreign distribution, in 1868.

Address.	No. of packages.
ALBANY, NEW YORK.	
New York State University	120
Professor J. Hall	112
ANN ARBOR, MICHIGAN.	
J. E. Watson	22
BALTIMORE, MARYLAND.	
Dr. P. R. Uhler	2
T. H. Wynne	1
BOSTON, MASSACHUSETTS.	
American Academy of Arts and Sciences	130
Boston Society of Natural History	275
Massachusetts Board of State Charities	62
Public Library	9
Robert E. C. Stearns	5
Dr. D. H. Storer	6
F. H. Storer	1
CAMBRIDGE, MASSACHUSETTS.	
Cambridge Observatory	5
Harvard College	21
Museum of Comparative Zoology	503
Professor L. Agassiz	140
CHICAGO, ILLINOIS.	
Chicago Academy of Sciences	74
COLUMBUS, OHIO.	
Ohio State Board of Agriculture	89
State of Ohio	1
Leo Lesqereux	30
DORCHESTER, MASSACHUSETTS.	
Dr. E. Jarvis	5
ERIE, PENNSYLVANIA.	
Rev. L. G. Olmstead	12
HAVANA, CUBA.	
Professor F. Poey	5
HARTFORD, CONNECTICUT.	
American Asylum for Deaf and Dumb	19
INDIANAPOLIS, INDIANA.	
Indiana Institution for Deaf and Dumb	15
Indiana Institution for Education of Blind	100
IOWA CITY, IOWA.	
Iowa Grand Lodge Masons	34
ITHACA, NEW YORK.	
Cornell University	25
LOWELL, MASSACHUSETTS.	
James B. Francis	8
MONTREAL, CANADA.	
Dr. J. W. Dawson	27
NEW HAVEN, CONNECTICUT.	
American Oriental Society	3
Cabinet of Yale College	1
Professor G. J. Brush	7
Professor J. D. Dana	24
Professor E. Loomis	16
Professors Silliman and Dana	26
Professor A. E. Verrill	10
NEW ORLEANS, LOUISIANA.	
New Orleans Academy of Natural Science	1
NEW YORK, NEW YORK.	
American Bureau of Mines	4
American Christian Commission	53
American Microscopical Society	50
New York Lyceum of Natural History	117
A. M. Edwards	1
D. Van Nostrand	15
NORTHAMPTON, MASSACHUSETTS.	
State Lunatic Hospital	17
PHILADELPHIA, PENNSYLVANIA.	
Academy of Natural Sciences	190
Academy of Natural Sciences, (Conchological section)	12

Packages received from parties in America, &c.—Continued.

Address.	No. of packages.	Address.	No. of packages.
PHILADELPHIA, PA.—Continued.		SAN FRANCISCO, CALIFORNIA.	
American Entomological Society	48	California Academy of Natural Sciences	54
American Pharmaceutical Association	25		
American Philosophical Society	278	SANTIAGO, CHILE.	
Historical Society of Pennsylvania	22	University of Chile	20
Pennsylvania Institution for Instruction of Blind	59		
James J. Barclay	209	SPRINGFIELD, ILLINOIS.	
G. W. Childs	600	A. H. Worthen	9
Dr. Isaac Lea	1		
Dr. J. H. Packard	250	TORONTO, CANADA.	
Edw Shippen, President of Board of Controllers of Public Schools	200	Canadian Institute	9
PRINCETON, NEW JERSEY.		WASHINGTON, D. C.	
A. D. Brown	2	American Nautical Almanac	85
PROVIDENCE, RHODE ISLAND.		Columbia Institute for Deaf and Dumb	125
Edwin M. Snow	31	Department of Agriculture	323
		Department of Education	1
ROCHESTER, NEW YORK.		Department of Interior	14
Darrow & Kempshall	2	General Land Office	2
		Library of Congress	17
ROCKFORD, ILLINOIS.		Surgeon General United States army	2
M. S. Bebb	1	United States Coast Survey	260
		United States Naval Observatory	87
ST. LOUIS, MISSOURI.		United States Patent Office	484
St. Louis Academy of Sciences	24	L. F. De Pourtales	14
Dr. G. Engelmann	14	A. R. Roessler	1
		Henry Ulke	1
SALEM, MASSACHUSETTS.		ADDRESS UNKNOWN.	
Essex Institute	189	Charles P. Clever	9
A. Hyatt	31	Dr. Edwards	12
A. S. Packard	26	F. N. Hasselquint	1
		Mrs. Mary Mann	6
		G. S. Wagner	1
			6,054

Packages received by the Smithsonian Institution from Europe, in 1868, for distribution in America.

Address.	No. of packages.
ALBANY, NEW YORK.	
Albany Institute	5
Bureau of Military Statistics	4
Dudley Observatory	17
New York State Agricultural Society	20
New York State Library, Albany	23
New York State Medical Society	3
New York State University	3
State Cabinet of Natural History, Albany	4
AMHERST, MASSACHUSETTS.	
Amherst College	4
ANNAPOLIS, MARYLAND.	
United States Naval Academy	3
ANN ARBOR, MICHIGAN.	
Observatory	5
University of Michigan	1
ATHENS, OHIO.	
Ohio University	1
AUBURN, NEW YORK.	
New York Lunatic Asylum for Convicts	1
AUGUSTA, MAINE.	
State Lunatic Hospital	2
AUSTIN, TEXAS.	
State Library	1
Texas State Lunatic Hospital	1
BALTIMORE, MARYLAND.	
Maryland Historical Society	4
Maryland Hospital for Insane	1
Mount Hope Institution	1
Peabody Institute	1
BLACKWELL'S ISLAND, NEW YORK.	
City Lunatic Asylum	1
BLOOMINGTON, INDIANA.	
Indiana State University	1
BOSTON, MASSACHUSETTS.	
American Academy of Arts and Sciences	94
American Christian Examiner	3
American Social Science Association	1
American Statistical Association	8
American Unitarian Association	3
Boston Christian Register	2
Boston Society of Natural History	189
Bowditch Library	3
City Lunatic Asylum	1
Massachusetts Historical Society	3
Massachusetts School of Technology	1
New England Historico-Genealogical Society	1
North American Review	2
Perkins Institution for Blind	1
Prison Discipline Society	1
Public Library	10
State Library	3
BRATTLEBORO', VERMONT.	
Vermont Asylum for Insane	1
BRUNSWICK, MAINE.	
Bowdoin College	2
Historical Society of Maine	3
BURLINGTON, VERMONT.	
University of Vermont	2
CAMBRIDGE, MASSACHUSETTS.	
American Association for Advancement of Science	22
Astronomical Journal	3
Harvard College	17
Harvard Natural History Society	1
Herbarium of Harvard College	2
Museum of Comparative Zoology	26
Observatory of Harvard College	31
CHARLESTON, SOUTH CAROLINA.	
Charleston Journal of Medicine	1
Elliott Society of Natural History	12
Society Library	1
South Carolina Historical Society	1
CHARLOTTESVILLE, VIRGINIA.	
University of Virginia	2

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
CHARLOTTETOWN, PRINCE EDWARD ISLAND.	
Royal Agricultural Society	1
CHICAGO, ILLINOIS.	
Chicago Academy of Sciences	51
Dearborn Observatory	8
Mechanics' Institute	1
CINCINNATI, OHIO.	
Mechanics' Institute	2
Observatory	1
COLUMBIA, MISSOURI.	
Geological Survey of Missouri	11
University	1
COLUMBIA, SOUTH CAROLINA.	
South Carolina College	1
State Lunatic Asylum	1
COLUMBUS, OHIO.	
Central Lunatic Asylum	1
Ohio Lunatic Asylum	1
Ohio State Board of Agriculture	60
CONCORD, NEW HAMPSHIRE.	
New Hampshire Asylum for Insane	1
New Hampshire Historical Society	2
DAYTON, OHIO.	
Southern Lunatic Asylum	1
DECORAH, IOWA.	
Lutheran College	1
DES MOINES, IOWA.	
State of Iowa	13
DETROIT, MICHIGAN.	
Michigan State Agricultural Society	14
FLATBUSH, NEW YORK.	
Kings County Lunatic Asylum	1
FLUSHING, NEW YORK.	
Sanford Hall Asylum	1
FRANKFORD, PENNSYLVANIA.	
Asylum for Insane	1
FRANKFORT, KENTUCKY.	
Geological Survey of Kentucky	4
FREDERICTON, NEW BRUNSWICK.	
Board of Agriculture	1
King's College	1
Legislative Library	1
FULTON, MISSOURI.	
Lunatic Hospital	1
GAMBIER, OHIO.	
Kenyon College	1
GEORGETOWN, D. C.	
Georgetown College	6
GREENCASTLE, INDIANA.	
Indiana Asbury University	1
HALIFAX, NOVA SCOTIA.	
Dalhousie University	1
Nova Scotian Institute of Natural Science	1
HAMILTON, NEW YORK.	
Madison University	1
HANOVER, NEW HAMPSHIRE.	
Dartmouth College	2
HARRISBURG, PENNSYLVANIA.	
State Library	1
State Lunatic Hospital	1
HARTFORD, CONNECTICUT.	
Retreat for Insane	1
Young Men's Institute	1
HOPKINSVILLE, KENTUCKY.	
Western Lunatic Asylum	1
INDIANAPOLIS, INDIANA.	
Hospital for Insane	1
Indiana Historical Society	1

Packages received from Europe, &c.—Continued.

Address.	No of packages.
INMANSVILLE, WISCONSIN.	
Wisconsin Scandinavian Society	1
IOWA CITY, IOWA.	
Iowa State University	14
ITHACA, NEW YORK.	
Cornell College	1
JACKSON, LOUISIANA.	
Lunatic Asylum	1
JACKSON, MISSISSIPPI.	
State Lunatic Asylum	1
JACKSONVILLE, ILLINOIS.	
Hospital for Insane	1
Institution for Blind	1
JANESVILLE, WISCONSIN.	
Institution for Blind	3
JEFFERSON CITY, MISSOURI.	
Historical and Philosophical Society	1
JESUS ISLE, CANADA.	
Observatory of St. Martin	1
KALAMAZOO, MICHIGAN.	
Hospital for Insane	1
KINGSTON, CANADA.	
Botanical Society of Canada	1
Observatory	1
KINGSTON, JAMAICA.	
Jamaica Society of Arts	1
LEBANON, TENNESSEE.	
Cumberland University	1
LEWISBURG, PENNSYLVANIA.	
University	1
LEXINGTON, KENTUCKY.	
Eastern Lunatic Asylum	1
LITCHFIELD, CONNECTICUT.	
Retreat for Insane	1
LITTLE ROCK, ARKANSAS.	
State Library	16
LOUISVILLE, KENTUCKY.	
University of Louisville	1
MADISON, WISCONSIN.	
Skandinaviske Presseforening	1
State Historical Society of Wisconsin	5
State Library	6
Wisconsin Natural History Society	1
Wisconsin State Agricultural Society	24
MIDDLETOWN, CONNECTICUT.	
Wesleyan University	1
MILL CREEK, OHIO.	
Lunatic Asylum	1
MILLEDGEVILLE, GEORGIA.	
State Lunatic Asylum	1
University	1
MONTPELIER, VERMONT.	
State Library	3
MONTREAL, CANADA.	
Geological Survey of Canada	1
Historical Society	1
McGill College	1
Natural History Society	28
Société d'Agriculture du Bas Canada	1
NASHVILLE, TENNESSEE.	
Hospital for Insane	1
University of Nashville	1
NEW BRUNSWICK, NEW JERSEY.	
Geological Survey of New Jersey	9
NEWBURG, OHIO.	
Northern Lunatic Asylum	1
NEW HAVEN, CONNECTICUT.	
American Journal of Science and Art	42

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
NEW HAVEN, CONN.—Continued.	
American Oriental Society	17
Connecticut Academy of Sciences	20
Yale College	13
NEW ORLEANS, LOUISIANA.	
New Orleans Academy of Sciences	28
NEW YORK, NEW YORK.	
American Christian Commission	21
American Eclectic Medical Review	2
American Ethnological Society	13
American Geographical and Statistical Society	31
American Journal of Mining	2
American Institute,	16
American Microscopical Society	1
Astor Library	5
Bloomingdale Asylum for Insane	1
Columbia College	1
Herbarium of Columbia College	1
Historical Society	2
Lyceum of Natural History	74
Mercantile Library Association	1
New York Academy of Medicine	1
New York Christian Inquirer	1
New York Journal of Medicine	1
School of Mines	6
United States Sanitary Commission	7
University	4
NORTHAMPTON, MASSACHUSETTS.	
State Lunatic Hospital	1
OXFORD, OHIO.	
Miami University	1
PHILADELPHIA, PENNSYLVANIA.	
Academy of Natural Sciences	159
American Entomological Society	12
American Journal of Medical Science	4
American Pharmaceutical Association	27
American Philosophical Society	82
Central High School	1
Franklin Institute	29
Historical Society of Pennsylvania	7
House of Refuge	1
Journal of Conchology	3
Library Company	2
Medical Chirurgical Review	2
Observatory of Girard College	1
Pennsylvania Horticultural Society	3
Pennsylvania Hospital for Insane	1
Pennsylvania Institution for Blind	1
PHILADELPHIA, PA.—Continued.	
Pennsylvania Institution for Deaf and Dumb	1
Philadelphia Hospital	1
Philadelphia Journal of Medicine	1
Philadelphia Society for Alleviating the Miseries of Public Prisons	1
Wagner Free Institute	4
PITTSBURG, PENNSYLVANIA.	
Western Hospital for Insane	1
PORTLAND, MAINE.	
Portland Society of Natural History	22
POUGHKEEPSIE, NEW YORK.	
Vassar College	2
PRINCETON, NEW JERSEY.	
College of New Jersey	6
PROVIDENCE, RHODE ISLAND.	
Brown University	1
Butler Hospital for Insane	1
Rhode Island Historical Society	3
QUEBEC, CANADA.	
Astronomical Observatory	1
Library of Parliament	1
Literary and Historical Society of Quebec	2
RALEIGH, NORTH CAROLINA.	
Insane Asylum	1
RICHMOND, VIRGINIA.	
State Library	1
ST. JOHN'S, NEW BRUNSWICK.	
Natural History Society of New Brunswick	2
Newfoundland Agricultural Society	1
ST. LOUIS, MISSOURI.	
Deutsche Instituts zur Beförderung von Wissenchaften	1
Mercantile Library	1
St. Louis Academy of Science	96
University	1

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
ST. PAUL, MINNESOTA.	
Minnesota Historical Society	1
SALEM, MASSACHUSETTS.	
Essex Institute	37
SAN FRANCISCO, CALIFORNIA.	
California Academy of Natural Science	49
SAVANNAH, GEORGIA.	
Historical Society of Georgia	1
SHELBYVILLE, KENTUCKY.	
Shelby College	1
SOMERVILLE, MASSACHUSETTS.	
McLean Asylum	1
STAUNTON, VIRGINIA.	
Western Lunatic Asylum	1
STOCKTON, CALIFORNIA.	
Hospital for Insane	1
TAUNTON, MASSACHUSETTS.	
State Lunatic Hospital	1
TORONTO, CANADA.	
Magnetic Observatory	5
Canadian Institute	9
University	2
TRENTON, NEW JERSEY.	
State Lunatic Asylum	1
UTICA, NEW YORK.	
American Journal of Insanity	5
State Lunatic Asylum	1
WASHINGTON, D. C.	
American Nautical Almanac	7
Bureau of Navigation	3
Bureau of Statistics	3
Department of Agriculture	17
Department of Education	3
Library of Congress	46
Light-house Board	1
Medical Department United States army	59
National Academy of Science	19
National Deaf-Mute College	1
Odd Fellows' Library	1
Ordnance Bureau	2
Secretary of the Interior	2
Secretary of War	4
State Department	4
Treasury Department	2
United States Coast Survey	22
United States Government Hospital for Insane	1
United States Land Office	8
United States Naval Observatory	93
United States Patent Office	140
Washington public schools	2
WATERVILLE, MAINE.	
Waterville College	1
WEST POINT, NEW YORK.	
United States Military Academy	2
WILLIAMSBURG, VIRGINIA.	
Eastern State Lunatic Asylum	2
WORCESTER, MASSACHUSETTS.	
American Antiquarian Society	6
State Lunatic Hospital	1

Total addresses of institutions	245	
Total addresses of individuals	191	
		436
Total number of parcels to institutions	2,208	
Total number of parcels to individuals	686	
		2,894

LIST

OF

SMITHSONIAN METEOROLOGICAL STATIONS AND OBSERVERS IN NORTH AMERICA AND ADJACENT ISLANDS FROM 1849 UP TO THE END OF THE YEAR 1868.

Those marked with a * are deceased.

Name of station.	Name of observer.	Years of observations.
ANTILLES.		
Sombrero Island	Alexis Julien	1863–'64
Sombrero Island	Milton Brayton	1865
BAHAMAS.		
Turk's Island	J. B. Hayne	1859
Turk's Island	J. C. Crisson, Capt. W. Hamilton.	1860
Turk's Island	*A. G. Carothers	1861
Turk's Island	United States consul	1862–'65
Turk's Island	J. C. Crisson, United States vice consul.	1868
Turk's Isl., Salt Cay	Samuel G. Garland	1861
Nassau, N. P.	A. M. Smith	1858–'59
BERMUDA.		
Hamilton	Capt. Alexander, R.E.	1852
Hamilton	Royal Gazette	1857
Shelby Bay	James B. Arnold	1857
St George's	James Crawford	1858
St. George's	Centre signal station, Royal Engineers, in Royal Gazette.	1858–'68
Ireland Island	John G. Calder	1859
CANADA.		
Clifton	W. Martin Jones, U. States consul.	1867–'68
Hamilton	Dr. W. Craigie	1857–'62
Kingston	J. Williamson, (dire'r Kingston Observ'y.)	1859–'60
Michipicoten	Colin Rankin	1860–'66
Montreal	Dr. A. Hall	1855–'63
Montreal	Thos. Blackwell	1861
Niagara	H. Phillips	1861–'63
Port Neuf	Observations publis'd in the Naturaliste Canadien.	1868
St. Martin's, near Montreal.	Dr. Chas. Smallwood.	1852–'62
Stanbridge	J. C. Baker	1857–'65
Stanbridge	A. H. Gilmour	1868
Stratford	C. J. Macgregor	1861–'62
Toronto	Magnetic Observatory	1856–'68
Toronto	Capt. J. H. Lefroy	1849 1851–'52
COSTA RICA.		
Limon	Felipe Valentin	1865–'66
San José	C. N. Riotte	1862–'66
San José	Dr. A. Von Frantzius.	1866–'67
San José	Oficina Central di Estadistica.	1867–'68
GUATEMALA.		
Guatemala	Antonia Canudas	1858–'62
HONDURAS.		
Belize	S. Cockburn	1862–'68
Truxillo	E. Purdot	1854

Name of station.	Name of observer.	Years of observations.
HUDSON'S BAY TERRITORY.		
Abbitibbe post	Jas. Lockhart	1868
Fort Anderson	R. Macfarlane	1863
Fort George	R. Macfarlane	1863
Fort Liard	*R. Kennicott	1860
Fort Nascopee	H. Connolly	1863–'65
Fort Norman	Andrew Flett	1862–'63
Fort Rae	Lawrence Clark, jr	1859–'60
Fort Rae, Great Slave L.	Mrs. Lawrence Clarke, jr.	1861–'64
Fort Simpson, Grt. Slave L.	B. R. Ross	1848–'61
Kenoqumissee	Thos. Richards	1861–'63
Little Whale River	Walter Dickson	1862
Moose Factory	J. Mackenzie	1857–'62
Moose Factory to Lake Superior.	Colin Rankin	1862
Red River settlem't.	Donald Gunn	1857–'61
Rigolet, Labrador	H. Connelly	1859–'60
JAMAICA.		
Upper Park Camp	James G. Sawkins	1855–'56
Upper Park Camp	Col. W. B. Marlow	1855
MEXICO.		
Chinamaca	Charles Laszlo	1859
Cordova	J. A. Hleto	1858–'60 1862, '64
Frontera, Tabasco	Charles Laszlo	1865
Mexico	Prof. L. C. Ervendberg	1855–'56
Minititlan	Charles Laszlo	1858–'60
Mirador	Dr. Chas. Sartorius	1858–'68
San Juan Bautiste	Charles Laszlo	1861–'64
Tuspan	Benjamin Crowther	1867
Vera Cruz	Herman Berendt, M.D.	1859
NEW BRUNSWICK.		
St. Johns	G. Murdock	1859–'68
NEWFOUNDLAND.		
St. Johns	*Jno. Delany, jr., and *E. M. J. Delany.	1857–'64
St. Johns	H. B. M. Milit'y Post.	1849
St. Johns	Rev. R. C. Caswell, M. A.	1868
NEW GRANADA.		
Aspinwall	W. T. White, M. D.	1857–'65
Aspinwall	*J. P. Kluge, M. D.	1865–'66 1868
Aspinwall	*J. P. Kluge, M. D., and G. V. Rucker, M. D.	1867
NICARAGUA.		
....	J. Moses	1855

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
NOVA SCOTIA.		
Halifax	Royal Engineers	1859–'61
Halifax	Col. W. J. Myers, F. B. M.	1863–'65
Halifax	Board of Trade	1854
Halifax	R. J. Nelson	1859
Horton	C. F. Hartt	1858
Pictou, (Albion Mines.)	Henry Poole	1843–'55
Windsor	King's College	1857–'62
Wolfville	Acadia College	1854 1860–'62
Wolfville	Prof. D. F. Higgins	1867–'68
Wolfville	C. F. Hartt	1859
Wolfville	Prof. A. P. S. Stuart	1855–'58
PORTO RICO.		
Est. San Ysidro	George Latimer	1868
SAN SALVADOR.		
La Union	Charles Dorat, M. D	1858
ST. DOMINGO.		
....	Jonathan Elliott	1860
VANCOUVER'S ISLAND.		
Victoria	David Walker, M. D	1863–'64
ALABAMA.		
Ashville	Thomas M. Barker	1857
Auburn	Prof. John Darby	1854–'58
Benton	Dr. Chas. F. Percival	1849–'51
Boligee	Col. Horace Harding	1860
Bon Secours	W. J. Van Kirk	1866–'67
Cahaba	Matthew Troy, M. D	1859
Carlowville	H. L. Alison, M. D	1856–'60 1867–'68
Erie	Dr. Sam'l K. Jennings	1849
Erie	Dr. T. C. Osborne	1851–'52
Eutaw	A. Winchell	1851–'52
Fish River	W. J. Van Kirk	1868
Greensboro'	Robert B. Waller	1856–'62
Greensboro'	N. T. Lupton	1868
Green Springs	H. Tutwiler	1854–'58
Havana	Prof. H. Tutwiler	1853 1859–'61 1866–'68
Havana, six miles east of.	S. K. Jennings, M. D	1868
Livingston	Rev. S. U. Smith	1859–'60
McMath's P. O	R. T. Meriwether	1854
Mobile	Dr. S. B. North	1849
Mobile	Rev. J. J. Nicholson	1859
Monroeville	S. J. Cumming	1849 1851–'55
Montgomery	Rev. J. A. Shepherd	1859–'61
Montgomery	W. L. Foster	1859–'60
Moulton	Andrew J. Harris	1866
Moulton	Thomas J. Peters	1866–'68
Moulton	Prof. J. Shackelford	1861
Moulton	Ashley D. Hunt	1859
Opelika	J. H. Shields	1867–'68
Orville	Dr. S. K. Jennings	1859–'60
Orville	T. A. Huston and J. A. Coleman.	1960
Prairie Bluff	William Henderson	1867
Prairie Bluff	R. M. Reynolds	1867
Selma	Dr. S. K. Jennings	1858–'59
Spring Hill	A. Cornette, S. J	1866
Tuscaloosa	Prof. M. Tuomey	1853–'54
Tuscaloosa	George Benagh	1854–'55
Union Springs	J. L. Moultrie	1868
Uniontown	Rev. R. A. Cobbs	1859–'60
Wetokaville	Benj. F. Holly	1849 1851–'54
ALASKA.		
Fort Youkon	* R. Kennicott	1861
Nulato	W. H. Dall	1866–'67
Sitka	Dr. Alex. H. Hoff	1867–'68
St. Michaels	H. M. Bannister	1865–'66
St. Michaels	J. M. Bean	1865–'66
Unalakleet	F. Westdahl	1866–'67
ARIZONA.		
Fort Whipple	Dr. E. Coues, U. S. A	1865
ARKANSAS.		
Arkadelphia	Dennis Barlow	1859
Arkadelphia	Female College	1860
Bentonville	Paul Graham	1859–'61
Brownsville	B. F. Coulter	1859–'60
Buckhorn	Armistead Younger	1859
Doaksville	Miss Sue McBeth	1860
Fort Smith	Rev. Francis Springer	1866–'67
Gainesville	James T. Davies	1859
Green Grove	Robert Burris, M. D	1860
Helena	O. F. Russell	1865–'68
Jacksonport	G. Alexander Martin, M. D	1859–'60
Little Rock	Philip L. Anthony	1849
Micco	Rev. H. F. Buckner	1860
Mountain Home	J. S. Howard	1861
Perryville	W. H. Blackwell	1859–'61
Perryville	H. F. Hardy	1856
Spring Hill	P. F. Finley	1859
Spring Hill	J. Reynolds	1859–'60
Spring Hill	P. F. Finley and J. Reynolds.	1860
Waldron	Geo. W. Featherstone	1859–'60
Washington	Alex. P. Moore, M. D	1861
Washington	Dr. N. D. Smith	1849–'61
Yellville	J. W. Weast	1859–'60
Yellville	W. B. Flippin	1859–'60
CALIFORNIA.		
Auburn	Robert Gordon	1859–'60
Columbia	Silas Earle, M. D	1857–'60
Crescent City	Robert B. Randall	1859–'60
Downieville	T. R. Kibbe, M. D	1860
Folsom	Rev. S. V. Blakeslee	1861
Fort Yuma	....	1867
Honcut	James Slaven	1859
Honcut	J. Slaven and Mrs. E. S. Dunkum.	1860
Honcut	Mrs. E. S. Dunkum	1861–'63
Mare Island	U. S. Naval Hospital	1868
Marsh's Ranche	Francis M. Rogers	1867–'68
Martinez	Edwin Howe	1860
Marysville	W. C. Belcher	1857–'59 1861–'63
Meadow Valley	James H. Whitlock	1860–'62
Meadow Valley	Colbert A. Canfield, M. D.	1864
Meadow Valley	M. D. Smith	1863–'68
Mokelumne Hill	Wesley K. Boucher	1859–'61
Monterey	Colbert A. Canfield, M. D.	1859–'60 1864–'68
Murphy's	Ephraim Cutting	1868
Presidio of San Francisco.	W. W. Hays, M. D	1862
Presidio of San Francisco.	D. F. Parkinson	1863–'64
Presidio of San Francisco.	Post surgeon	1852–'61
Sacramento	Dr. F. W. Hatch	1851
Sacramento	Drs. F. W. Hatch and T. M. Logan.	1855
Sacramento	Dr. T. M. Logan	1849–'68
Sacramento	Charles Craft	1863
San Francisco	W. O. Ayres, M. D	1856–'63 1865–'68
San Francisco	Dr. H. Gibbons	1854–'55

List of Smithsonian meteorological stations and observers.—Continued.

Name of station.	Name of observer.	Years of observations.
CALIFORNIA—Con.		
Santa Barbara	W. W. Hays, M. D.	1864
Santa Clara	Prof. O. S. Frombes	1859–'61
Santa Clara	Lewis A. Gould	1859
Spanish Ranche	M. D. Smith	1862–'63
Spanish Ranche	Mrs. M. D. Smith	1864–'66
Stockton	Dr. Robert K. Ried	1855–'56
Stockton	Walter M. Trivett	1867
Union Ranche	W. L. Dunkum	1858
COLORADO.		
Central City	W. D. McLain	1860–'61
Denver City	D. C. Collier	1859
Denver City	Fred. J. Stanton	1862
Fountain	Arthur M. Merriam	1866–'67
Golden City	E. L. Berthoud	1867
Montgomery	James Lutrell	1863–'65
Mountain City	Dr. William T. Ellis	1860–'62
CONNECTICUT.		
Brookfield	Sanford W. Roe	1868
Canton	Jarvis Case	1861–'63
Colebrook	Miss C. Rockwell	1860–'68
Columbia	W. G. Yeomans	1856–'68
East Windsor Hill	P. A. Chadbourne	1852
Georgetown	Aaron B Hull	1855–'57
Groton	Rev. E. Dewhurst	1866–'68
Hartford	Charles H. Hoadley	1849–'51
Middletown	Prof. J. Johnston	1854, '58 1859–'68
Middletown	* Prof. A. W. Smith	1849, '51 1852
New Haven	H. G. Du Bois, jr	1859
New Haven	D. C. Leavenworth	1862–'64
New Haven	Prof. E. Cutler	1849, '51
New London	Rev. Tryon Edwards, D. D.	1849, '51 1852–'58
North Colebrook	M. H. Cobb	1849, '51
Norwich	N. Scholfield	1855–'58
Plymouth	Dwight W. Learned	1862–'64
Pomfret	Rev. Daniel Hunt	1853–'68
Salisbury	Dr. Ovid Plumb	1849, '51 1853–'54
Saybrook	James Rankin	1853–'61
Wallingford	Benj. F. Harrison	1856–'62
Waterbury	Rev. R. G. Williams	1867–'68
West Cornwall	T. S. Gold	1854
Windsor	R. H. Phelps	1851
DAKOTA.		
Fort Union	F. G. Riter	1857–'58
Greenwood	Freeman Norvell	1859–'61
Yancton	M. K. Armstrong	1865
Yancton	G. D. Hill, G. W. Lawson, H. G. Williams.	1862
Yancton	H. G. Williams	1863
DELAWARE.		
Delaware City	L. Vankekle	1866–'67
Dover	J. P. Walker	1854
Georgetown	Dr. D. W. Mauld	1859
Lewes	John Burton	1849
Milford	R. A. Martin	1857–'58
Newark	Prof. W. A. Norton	1849
Newark	Prof. E. D. Porter	1852
Newark	Prof. W. A. Crawford	1854
Newark	Prof. W. A. Crawford, R. A. Martin.	1855
Newark	Prof. W. A. Crawford, R. A. Martin, and T. J. Craven.	1856
Newark	Thos. J. Craven and Mrs. E. D. Porter.	1857
Newark	Mrs. E. D. Porter	1858
Newark	Robert Crawford	1856
Wilmington	* Urban D. Hedges	1863–'65

Name of station.	Name of observer.	Years of observations.
DIST. OF COLUMBIA.		
Georgetown	Rev. C. B. McKee	1860–'63
Washington	U. S. N. Observatory	1852–'60 1864–'67
Washington	J. Wiessner	1857–'58
FLORIDA.		
Alligator	Edward R. Ives	1857–'58
Atsena Otie	Hon. Aug. Steele	1859–'61
Belair	Benj. F. Whitney	1857–'58
Cedar Keys	Judge Aug. Steele	1851–'58
Cedar Keys	W. C. Andrus	1867
Chesnut Hill	John Newton	1851
Fernandina	*Henry M. Corey	1867
Gainesville	James B. Bailey	1855–'61
G[illegible]on	P. C. Garvin, M D.	1866
Gordon	H. B. Scott	1866–'68
Green Cove Spring	G. A. Boardman	1868
Hibernia	F. L. Bachelder	1857–'58
Jacksonville	Dr. A. S. Baldwin	1853–'60 1866–'68
Key West (Salt Pond.)	W. C. Dennis	1854–'64
Key West (Magnetic Observa'y.)	George D. Allen	1860–'61
Key West (Magnetic Observa'y.)	G. F. Ferguson, and J. G. Oltmans.	1861–'62
Knox Hill	John Newton	1852–'53
Lake City	Edward R. Ives	1859–'60 1866–'68
Lake City	Galen M. Fisher	1867
Lake City	Rev. W. W. Keep	1868
Micanopy	Dr. James B. Bean	1858–'60
Orange Hills	John Newton	1854
Pensacola	U. S. Navy Yard	1849 1857–'60
Pensacola	J. Pearson, U. S. N.	1851–'54
Pensacola	J. Pearson and Lieut. Joseph Fry.	1855
Pensacola	Lieut. Joseph Fry	1856
Pensacola	Lieuts. Jos. Fry and J. W. Hester.	1857
Pensacola	Lieut. J. W. Hester	1858
Port Orange	J. M. Hawks, M. D.	1867–'68
St. Augustine	Dr. John E. Peck	1849
St. Augustine	P. B. Mauran, M. D.	1856–'60
Tallahassee	Benj. F. Whitner	1859–'61
Tallahassee	W. S. Bogert	1852
Tallahassee	Lardner Gibbon	1859–'60
Uchee Anna	John Newton	1849
Warrington	Thayer Abert	1859–'60
GEORGIA.		
Athens	Prof. John D. Easter	1857–'59
Atlanta	J. G. Westmoreland	1859–'60
Atlanta	Fred. Deckner & Son	1865–'68
Augusta	William Haines	1854–'57
Augusta	William Schley	1854
Augusta	Wm. H. Doughty, M. D	1858–'60
Boston	Rev. W. Blewitt	1865–'68
Clarksville	Jarvis Van Buren	1859–'61
Clarksville	Col. J. R. Stanford	1859
Covington	Benjamin F. Camp	1859–'61
Culloden	John Darby	1852–'53
Cuthbert	Charles C. Seavey	1860
Dalton	J. R. McAfee	1861
Darien	Charles Grant	1849
Factory Mills	F. T. Simpson	1857
Hillsboro'	Eli S. Glover	1857–'58
Macon	Miss L. J. Whitney	1868
Macon	John A Rockwell	1868
Macon	J. F. Adams	1868
Madison	Prof. Wm. D. Williams	1854
Milledgeville	J. M. Cotting	1849
Milledgeville	Prof. C. W. Lane	1849
Penfield	Prof. J. E. Willet	1852
Perry	Dr. Geo. F. Cooper	1851–'52
Philomath	James M. Reed	1857

List of Smithsonian meteorological stations and observers.—Continued.

Name of station.	Name of observer.	Years of observations.
GEORGIA—Con'd.		
Powelton	P. C. Pendleton	1852
Savannah	* Dr. John F. Posey	1852–'59
Savannah	R. T. Gibson	1859–'61
Sparta	Dr. E. M. Pendleton	1852–'61
Summerville	Stephen Elliott Habersham.	1868
The Rock	Dr. James Anderson	1855–'69
Thomasville	Rev. W. Blewitt	1868
Thomson	Dr. W. T. Grant	1858–'59
Whitemarsh Island	R. T. Gibson	1849–'58
Zebulon	Mrs. J. T. Arnold	1857–'59
IDAHO.		
Cantonment Jordan	W. W. Johnson	1859
Fort Benton	M. C. Rosseau	1863
Fort Halleck	J. H. Finfrock	1864
Fort Laramie	Col. W. O. Collins	1863–'64
Fort Laramie	A. F. Ziegler, M. D.	1865
ILLINOIS.		
Albany	Warren Olds	1861–'62
Albion	Edgar P. Thompson	1857
Alton	S. Y. McMasters	1849
Alton	Norton Johnson	1849
Andalusia	E. H. Bowman, M. D.	1866–'68
Athens	Joel Hall	1851–'58
Augusta	Dr. S. B. Mead	1849–'50
		1851–'68
Aurora	* Andrew J. Babcock	1857–'61
Aurora	Abiram Spaulding	1865–'68
Batavia	Prof. Wm. Coffin	1853–'54
Batavia	* Thomp'n Mead, M. D.	1857–'61
Batavia	E. Capen	1858–'59
Batavia	Frank Crandon	1861–'62
Belleville	N. T. Baker	1860–'63
Belleville	Dr. John J. Patrick	1861
Belleville	Dr. J. J. Patrick and N. T. Baker.	1862
Belvidere	G. B. Moss	1868
Bloomington	Jesse Allison	1859–'61
Brighton	Wm. V. Eldridge	1855–'58
Carbon Cliff	Mrs. Wm. S. Thomas	1859
Carthage	Samuel J. Wallace	1857
Carthage	Mrs. E. M. A. Bell & Sam'l J. Wallace.	1859
Centralia	H. A. Schauber	1865
Channahan	Rev. D. H. Sherman	1860
Channahan	Dr. Jos. Fitch	1861
Chicago	Henry Talcott	1851
Chicago	G. D. Hiscox	1856–'57
Chicago	Samuel Brookes	1859–'68
Chicago	M. C. Armstrong and J. H. Roe.	1860–'61
Chicago	Gustave A. Boettner	1860–'61
		1863
Chicago	A. M. Byrne, J. H. Roe, and others.	1862
Chicago	John O'Donoghoe	1862
Chicago	Arthur M. Byrne	1863–'64
Chicago	Isaac A. Pool	1866
Chicago	John G. Langguth, jr.	1867–'68
Clinton	C. H. Moore	1864–'66
De Kalb	John D. Parker	1866
Dixon	J. Thos. Little	1859–'63
		1867
Dongola	Ralph E. Meeker	1861–'62
Dubois	Wm. C. Spencer	1865–'68
Du Quoin	C. Ziegler	1861
Edgar county	J. W. Brown	1858
Edgington	Dr. E. H. Bowman	1857–'61
Elgin	Jno. B. Newcomb	1858–'61
Elmira	Orestes A. Blanchard	1862–'63
		1865–'68
Elmore	W. H. Adams	1861–'68
Evanston	* H. G. Meacham	1858
Evanston	Chas. E. Smith	1859–'60
Evanston	A. D. Langworthy	1864

Name of station.	Name of observer.	Years of observations.
ILLINOIS—Con'd.		
Evanston	* W. H. Morrison	1864
Evanston	H. W. Scovill	1864
Evanston	Jos. H. Gill and others	1865
Evanston	Fred. J. Huse	1866–'67
Evanston	Prof. Oliver Marcy	1866
Farmbridge	Elmer Baldwin	1860
Fremont Centre	Isaac H. Smith	1857–'58
Galena	Emil Hauser	1859–'60
Galesburg	Prof. Wm. Livingston	1861–'68
Golconda	Rev. Wm. V. Eldridge	1866–'68
Granville	L. G. Edgerly	1851
Granville	J. L. Jenkins	1857
Hazel Dell	Henry Griffing	1863–'65
Hennepin	Smiley Sheppard	1868
Highland	A. F. Bandelier, jr	1860–'64
Hillsboro	John S. Titcomb	1858
Hoylton	J. Ellsworth	1861–'65
Hoylton	O. J. Marsh	1866
Jacksonville	Prof. Wm. Coffin	1849
Jacksonville	Timothy Dudley	1858
		1861–'64
Lacon	A. H. Thompson	1867
Lebanon	Prof. N. E. Cobleigh	1859–'61
Loammi	Timothy Dudley	1867–'68
Magnolia	Henry K. Smith	1866–'68
Manchester	John Grant	1854–'61
Manchester	John Grant and Miss Ellen Grant.	1862–'65
Manchester	John & C. W. Grant	1866–'68
Marengo	O. P. Rogers	1856–'58
		1868
Marengo	O. P. & J. S. Rogers	1859–'63
		1865–'66
Marengo	F. Rogers	1868
Monroe	Silas Meacham	1849
Mount Sterling	Rev. Alex. Duncan	1866–'68
Naperville	Lewis Ellsworth	1859
Naperville	Milton S. Ellsworth	1859–'60
Newton	Rev. Wm. V. Eldridge	1859
North Prairie	C. H. Bryant	1862
Olney	Rev. H. H. Brickenstein.	1860
Osceola	J. S. Pashley, M. D.	1860–'61
Ottawa	Dr. J. O. Harris	1852–'61
Ottawa	Geo. O. Smith, M. D.	1859–'60
Ottawa	Samuel L. Shotwell	1860
Ottawa	Mrs. Emily H. Merwin	1862–'68
Paris	C. Leving	1868
Pekin	J. H. Riblet	1857–'65
Peoria	Dr. Fred. Brendel	1855–'68
Peoria	M. A. Breed	1861–'62
Plymouth	Dr. J. B. N. Klinger	1852
Quincy	Rev. G. B. Giddings	1849
Ridge Farm, Vermilion county.	B. C. Williams	1868
Riley	E. Babcock	1856–'67
Robinson's Mills	E. Brendel, M. D.	1860
Rochelle, (Alta)	Daniel Carey	1866–'68
Rockford	William Holt	1849
Sandwich	N. E. Ballou, M. D.	1859–'68
South Pass	Frank Baker	1857–'58
South Pass	S. C. Spaulding	1862–'66
South Pass	H. C. Freeman	1867–'68
Springfield	Geo. W. Brinkerhoff	1865–'68
Tiskilwa	Verry Aldrich	1859–'68
Upper Alton	Prof. P. P. Brown	1851–'52
Upper Alton	* Dr. John James	1853–'59
Upper Alton	Anna James	1857
Upper Alton	Mrs. Anna C. Trible	1861–'64
Wapella	T. Louis Groff	1858
Warsaw	Benj. Whitaker	1855–'58
Waterloo	H. Kunster	1865
		1867–'68
Waukegan	Dr. Wm. Joslyn	1849
Waverley	Timothy Dudley	1865–'66
Waynesville	Joshua E. Cantril	1858–'59
West Salem	Henry A. Titze	1855–'60
West Urbana	John Swain, M. D.	1857–'59
Wheaton	Prof. Geo. H. Collier	1858–'61

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
ILLINOIS—Con'd.		
Willow Creek	E. E. Bacon	1859–'63
Willow Hill	Henry Griffing	1862
Winnebago Depot	J. W. Tolman	1858–'68
Woodstock	Geo. R. Bassett	1859–'61
Wyanet	E. S. Phelps	1864
Wyanet	E. S. Phelps and Miss L. E. Phelps.	1865–'68
York Neck	V. P. Gay	1864–'65
INDIANA.		
Aurora	Geo. Sutton, M. D.	1859 1866–'68
Balbec	Miriam Griest	1865–'66
Bloomingdale	Wm. H. Hobbs	1864
Bloomingdale	Miss M. A. Hobbs	1865
Bloomington	Prof. C. M. Dodd, assisted by T. H. Mallow and others.	1868
Cadiz	Wm. Dawson	1854–'63
Cannelton	Hamilton Smith, jr.	1856–'61
Carthage	Charles M. Hobbs	1868
Columbia	Dr. F. McCoy and Miss Lizzie McCoy.	1865–'68
Evansville	John F. Crisp	1857–'58
Fort Wayne	Prof. A. C. Huestis	1849
Fort Wayne	Miss G. Webb	1860–'61
Greencastle	Prof. Jos. Tingley	1851–'54
Greencastle	Wm. H. Larrabee	1859–'63
Indianapolis	* Royal Mayhew	1861–'65
Indianapolis	W. W. Butterfield	1864–'65
Indianapolis	W. W. Butterfield and Mrs. Butterfield.	1866–'67
Indianapolis	W. J. Elstun	1867–'68
Jalapa	Albert C. Irwin	1868
Kendallville	W. B. Coventry	1854
Kendallville	J. Knauer	1854
Knightstown	D. Deem	1868
Lafayette	A. H. Bixby	1854
Lafayette	H. Peters	1854
Lafayette	Isaac E. Windle	1865
Laporte	R. M. Newkirk	1849
Leo	W. W. Spratt, M. D.	1861
Logansport	Charles B. Laselle	1857–'58
Logansport	Isaac Bartlett	1859–'61
Logansport	Tho. B. Helm	1863
Madison	C. Barnes	1854
Madison	Rev. Samuel Collins	1864–'66
Madison	Oliver Mulvey	1865
Merom	Thomas Holmes	1866–'68
Michigan City	C. S. Woodard	1857–'58
Michigan City	W. Woodbridge, B. D. Angell, and H. Blake.	1859–'60
Milton	Dr. V. Kersey	1853–'55
Mishawaka	Geo. C. Munfield	1859
Muncie	E. J. Rice	1863–'64
Muncie	G. W. H. Kemper	1866–'68
New Albany	C. Barnes	1855–'58
New Albany	Dr. Alex. Martin	1859
New Albany	Dr. E. S. Crozier	1863–'65
New Castle	Prof. Jos. Tingley	1849
New Castle	Thos. B. Redding	1863–'65
New Garden	D. H. Roberts	1854
New Harmony	John Chappelsmith	1852–'68
New Harmony	Dr. D. D. Owen	1849–'51 1867
Newport	Daniel H. Roberts	1851
Patoka	A. P. Turner	1859
Pennville	John Griest	1864
Rensselaer	J. H. Loughridge, M.D	1864–'65 1867–'68
Richmond	Dr. Jno. T. Plummer	1849, '51
Richmond	W. W. Austin	1851–'55 1859–'61
Richmond	Joseph Moore	1855–'59
Richmond	John Haines	1859–'63
Richmond	Edward B. Rambo	1862–'63
Richmond	John Valentine	1865–'68

Name of station.	Name of observer.	Years of observations.
INDIANA—Con'd.		
Rockville	H. H. Anderson	1859–'66
Rockville	J. W. Tenbrock	1859
Shelbyville	J. T. Bullock	1859–'62
South Bend	Prof. Gardner Jones	1851
South Bend, (Notre Dame Univer'y.)	Prof. Thos. Vagnier	1858–'59
South Bend	Miss G. Webb	1859
South Bend	James H. Dayton	1860–'63
South Bend	Reuben Burroughs	1863–'65
South Hanover	Prof. S. H. Thomson	1849
Spiceland	Wm. Dawson	1863–'68
Vevay	Charles G. Boerner	1864–'68
Walnut Hills	W. W. Austin	1849
INDIAN TERRITORY.		
Armstrong Acade'y	Prof. A. G. Moffatt	1849
Doaksville	P. P. Brown	1849
Talequah	T. B. Van Horne	1849
IOWA.		
Algona	F. McCoy, M. D.	1860
Algona	F. McCoy and Miss Elizabeth McCoy.	1861–'65
Algona	Philip Dorweiler	1866–'68
Algona	James H. Warren	1867–'68
Atalissa	B. Carpenter	1867
Bangor	Isaac M. Gidley	1861–'63
Bellevue	John C. Forey	1856–'60
Boonsboro	E. Babcock	1867–'68
Border Plains	G. C. and W. K. Goss	1856
Border Plains	Wm. K. Goss	1857–'59
Bowen's Prairie	Samuel Woodworth	1868
Burlington	John M. Corse	1859–'60
Burlington	Louisa P. Love	1866–'68
Burlington	Mrs. James Love	1868
Ceres	John M. Hagensick	1865–'68
Clarinda	S. H. Kridelbaugh, M. D.	1865–'66
Clinton	Nathan H. Parker	1856–'58
Clinton	P. J. Farnsworth	1866–'68
Dakota	Wm. O. Atkinson	1867–'68
Davenport	Nathan H. Parker	1858
Davenport	A. J. Finley	1859
Davenport	H. S. Finley	1859
Davenport	H. S. Finley and W. P. Dunwoody.	1860
Davenport	J. Chamberlain, W. P. Dunwoody, H. H. Belfield.	1861
Davenport	Dr. Ignatius Langer	1861
Davenport	H. H. Belfield and W. P. Dunwoody.	1862
Davenport	J. Chamberlain and W. P. Dunwoody.	1863
Davenport	J. Chamberlain	1864
Davenport	Geo. B. Pratt	1865
Davenport	G. B. Pratt and Sydney Smith.	1866
Davenport	D. S. Sheldon	1867–'68
Des Moines	Rev. J. A. Nash	1865–'67
Dubuque	Dr. Asa Horr	1851–'55 1857–'63
Dubuque, (Alexander College.)	Rev. Joshua Phelps	1854
Dubuque	Dr. W. W. Woolsey	1856
Fairbanks	Dexter Beal	1856
Fairfield	J. M. Shaffer	1856–'60
Fairfield	Miss Sue McBeth	1859
Fayette	John M. McKenzie	1859–'60
Fontanelle	A. F. Bryant	1866–'68
Forrestville	Daniel Sheldon	1859–'63
Fort Madison	Daniel McCready	1852, '54 1855–'68
Franklin	Dexter Beal and W. W. Beal.	1857
Franklin	Dexter Beal	1858

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
IOWA—Continued.		
Fort Dodge	C. N. Jorgenson	1867–'68
Grove Hill	Dexter Beal	1859–'60
Grove Hill	Dexter Beal and W. W. Beal.	1861
Grove Hill	Mrs. Celia Beal	1862
Guttenburg	Philip Dorweiler	1864–'66
Guttenburg	James P. Dickinson	1866–'68
Harris Grove	Jacob F. Stern	1866–'68
Hesper	H. B. Williams	1860–'61
Independence	D. S. Deering	1861–'67
Independence	Alex. Camp Wheaton	1862–'66
Independence	Mrs. D. D. Wheaton	1866–'68
Independence	Geo. Warne, M. D.	1867–'68
Iowa City	Hermann H. Fairall	1856
Iowa City	W. Reynolds	1857–'58
Iowa City	Prof. Theo. S. Parvin	1861–'68
Iowa Falls	Nathan Townsend	1863–'68
Keokuk	Miss Ida E. Ball	1851–'54
Keokuk	Dr. J. E. Ball	1853
Keokuk	Prof. K. M. Taylor	1866
Kossuth	Wm. P. Leonard	1862
Kossuth	Isaiah Reed	1860–'61
Lyons	A. T. Hudson, M. D	1859–'67
Lyons	P. J. Farnsworth	1862–'65
Lyons	Dr. J. Messman	1866
Manchester	* Allen Mead	1865–'66
Maquoketa	Edward F. Hobart	1857
Marble Rock	H. Wadey	1867–'68
Monticello	Chauncey Mead	1864–'66
Monticello	M. M. Moulton	1866–'68
Mount Pleasant	E. L. Briggs	1863–'64
Mount Vernon	Prof. B. Wilson Smith	1857
Mount Vernon	Prof. Alonzo Collins	1860–'68
Muscatine	T. S. Parvin	1849–'50 1851–'52 1855–'59
Muscatine	P. G. Parvin	1853–'54
Muscatine	Suel Foster	1860–'64
Muscatine	T. S. Parvin and Rev. John Ufford.	1860
Muscatine	Rev. John Ufford	1861–'62
Muscatine	Josiah P. Walton	1863–'68
Onowa	Richard Stebbins	1864
Osage	Rev. Alva Bush	1866–'67
Pella	E. H. A. Scheeper	1854–'56
Pleasant Plain	Townsend McConnell	1855–'65
Pleasant Spring	Rev. B. F. Odell	1858
Plum Spring	B. F. Odell and Miss Mary G. Odell.	1855
Plum Spring	Rev. B. F. Odell	1859
Poultney	Dr. B. F. Odell	1853–'54
Quasqueton	Dr. E. C. Bidwell	1853–'56
Rolfe	Oscar I. Strong	1868
Rossville	Carlisle D. Beaman	1857–'59
Sioux City	Dr. J. J. Saville	1857–'58
Sioux City	A. J. Millard	1861–'63
St. Mary's	D. E. Read	1853
Vernon Springs	Gregory Marshall	1861–'63
Washington	C. R. Boyle	1861
Waterloo	L. H. Doyle	1859–'64
Waterloo	T. Steed	1861–'68
Whitesboro	David K. Witter	1867–'68
KANSAS.		
Atchison	Dr. H. B. Horn and Miss Clotilde Horn.	1865–'68
Avon	Allen Crocker	1866
Baxter Springs	Ingraham & Hyland	1867–'68
Burlingame	* Lucian Fish	1859–'61
Cayuga	Wm. H. Gilman	1858
Celestville	Rev. J. H. Drummond	1859–'60
Council City	Edmund Fish	1857–'58
Council Grove	A. Woodworth, M. D	1865–'68
Emporia	C. F. Oakfield	1862
Fort Riley	Rev. David Clarkson	1859–'60
Fort Riley	Dr. Fred. P. Drew, U. S. A.	1862–'64
Fort Riley	Post Surgeon	1865

Name of station.	Name of observer.	Years of observations.
KANSAS—Con'd.		
Fort Riley	J. M. Shaffer and E. P. Camp.	1866
Gardner	G. F. Merriam	1860
Gardner	James Scott	1861–'62
Holton	Dr. James Walters	1867–'68
Junction City	E. W. Seymour, M. D.	1862
Lawrence	G. W. Brown	1857–'59
Lawrence	W. J. R. Backman	1860–'61
Lawrence	A. N. Fuller	1862–'64
Lawrence	W. L. G. Soule	1863–'64
Lawrence	Geo. W. Hollingworth	1867
Lawrence	Prof. F. H. Snow	1868
Leavenworth	H. D. McCarty	1857–'59 1868
Leavenworth	E. L. Berthoud	1858–'60
Leavenworth	M. Shaw	1861–'62
Leavenworth	Dr. J. Stayman	1866–'68
Leavenworth	T. B. Stowell	1868
Lecompton	Dr. Wm. T. Ellis	1859–'60
Lecompton	Wm. A. McCormick	1860–'61
Lecompton	David G. Bacon	1866
Leroy	J. G. Shoemaker	1867
Manhattan	Isaac T. Goodnow	1857–'62
Manhattan	Rev. N. O. Preston	1859–'60
Manhattan	I. T. Goodnow and H. L. Denison.	1863
Manhattan	Henry L. Denison	1864
Manhattan	Agricultural College. (B. F. Mudge, and and others.)	1865–'68
Mapleton	S. O. Himoe, M. D	1857–'58
Moneka	J. O. Wattles and Celestia Wattles.	1859
Neosho Falls	B. F. Goss	1859–'61
Neosho Falls	Mrs. E. W. Groesbeck	1868
Olatha	W. Beckwith	1864–'68
Ridgeway	O. H. Brown	1863
Topeka	F. W. Giles	1858
Wyandot	John H. Millar	1859–'60
KENTUCKY.		
Ballardsville	Dr. John Swain	1853–'56 1860–'62
Bardstown	*John H. Lunemann	1858
Bardstown	J. H. Lunemann and Thos. H. Miles.	1859
Bardstown	Thos. H. Miles	1860–'61
Beech Fork	Dr. C. D. Case	1860
Bowling Green	J. E. Younglove	1849–'50 185[illegible]–'52
Bowling Green	F. C. Herrick	1852
Chilesburg	Dr. Samuel D. Martin	1865–'68
Clinton	Rev. T. H. Cleland	1868
Danville	O. Beatty	1853–'62 1865–'68
Danville	R. H. Caldwell	1851
Drennon Springs	Prof. S. Y. McMasters	1851
Hardinsburg	Mrs. Mary A Walker and J. C. Barbage.	1859
Hardinsburg	Joshua C. Barbage	1860–'61
Lexington	J. D. Shane	1854
Lexington	Rev. S. R. Williams	1859 1867–'68
London	W. S. Doak	1865–'66
Louisville	Rev. S. R. Williams	1858–'59
Louisville	E. N. Woodruff	186[illegible]–'63
Maysville	E. L. Berthoud	1852–'54
Millersburg	Rev. J. Miller	1853
Millersburg	Rev. J. Miller, Rev. G. S. Savage.	1851
Millersburg	Dr. Geo. S. Savage	1855–'62
Newport	Prof. M. G. Williams.	186[illegible]
Nicholasville	Jos. McD. Matthews, D. D.	1861–'63
Nolin	J. Grinnell	1858
Paducah	Andrew Mattison	1859–'62
Paris	L. G. Ray	1851–'59
Pleasant Valley	A. H. Bixby	1853

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
KENTUCKY—Con'd.		
Prospect Hill	O. Beatty	1849–'51
Russellville	E. M. Murch	1860
Springdale, (near Louisville.)	Mrs. L. Young	1849–'50
		1851–'55
		1857–'68
Taylorsville	H. C. Mathis	1866
LOUISIANA.		
Benton	J. H. Carter	1867–'68
Falls River	A. W. Jackson, M. D.	1859
Grand Coteau	B. F. Anthonios	1860
Independence	Col. C. B. Swasey	1859
Independence	Mrs. M. J. Mankard	1860
Jackson	Prof. W. P. Riddell	1854
New Orleans	* Dr. E. H. Barton	1849, '50
		1851–'57
New Orleans	Lewis B. Taylor	1856–'57
		1859, '61
New Orleans	Dr. S. P. Moore, U. S. A.	1860
New Orleans	Harrison Thompson	1861
New Orleans	Robert W. Foster	1867–'68
New Orleans	E. L. Raulett	1868
St. Francisville	B. R. Gifford	1856
Tri ity	A. R. Kilpatrick, M. D.	1856–'59
Trinity	Edward Merrill, M. D.	1856–'58
		1860
Vidalia plantation	Rev. A. K. Teele	1867
MAINE.		
Bangor	Stephen Gilman	1849
Bangor	C. L. Nichols	1859–'60
Belfast	G. Emerson Brackett	1859–'64
Bethel	Rev. A. G. Gaines	1861–'62
Biddeford	J. G. Garland	1849–'50
		1851–'53
Biddeford	F. A. Small	1854
Blue Hill	Rev. S. H. Merrill	1854–55
Blue Hill	H. H. Osgood	1864
Brunswick	*Prof. Parker Cleaveland.	1849–'59
Bucksport	Rufus Buck	1849–'50
		1851–'52
Carmel	J. J. Bell	1853–'57
Castine	Dr. J. L. Stevens	1851
Cornish	G. W. Guptill	1855–'68
Cornish	Silas West	1857–'68
Dexter	B. F. Wilbur	1860–'63
East Exeter	Stephen Gilman	1858
East Wilton	Henry Reynolds, and Lauriston Reynolds.	1861–'63
Exeter	Dr. J. B. Wilson	1860–'61
Foxcroft	M. Pitman	1863–'64
Freedom	E. A. Buller	1859
Fryeburg	G. B. Barrows	1849–'56
Gardiner	*Hon. R. H. Gardiner.	1855–'64
Gardiner	Rev. F. Gardiner	1864
Gardiner	Rev. F. and R. H. Gardiner.	1865
Gardiner	R. H. Gardiner	1866–'68
Hartland	E. E. Brown, S. W. Hall, L. S. Strickland, and others.	1859
Hiram	Peleg Wadsworth	1849–'64
Houlton	Milton Welch	1849
Lee	Benj. H. Towle	1866–'67
Lee	E. Pitman	1864–'66
Limington	W. G. Lord	1859–'61
Lisbon	Asa P. Moore	1859–'68
Monson	B. F. Wilbur	1856–'59
Newcastle	C. L. Nichols	1859
New Sharon	J. F. Pratt, M. D.	1860–'62
North Belgrade	A. H. Wyman	1859–'60
North Bridgeton	M. Gould	1860–'61
North Prospect	Virgil G. Eaton	1867
Norway	G. W. Verrill, jr	1859–'61

Name of station.	Name of observer.	Years of observations.
MAINE—Con'd.		
Oldtown	Rev. S. H. Merrill	1849–'50
		1851–'53
Oxford	Howard D. Smith	1868
Patten	S. Eveleth	1849
Pembroke	Rev. E. Dewhurst	1862
Perry	William D. Dana	1853–'65
Portland	Henry Willis	1855–'60
Portland	John W. Adams	1859–'61
Rumford Point	Waldo Pettingill	1866–'68
Sebec	Edwin Pitman	1864
South Thomaston	Joshua Bartlett	1853–'54
Standish	John P. Moulton	1865–'68
Steuben	J. D. Parker	1849–'50
		1851–'68
Thomaston	George Prince and Chr. Prince.	1849–'50
		1851–'52
Topsham	Warren Johnson	1859–'61
Vassalboro	James Van Blarcom	185[illegible]–63
Warren	Calvin Bickford	1859–'60
Webster	Almon Robinson	1865–'67
West Waterville	B. F. Wilbur	1863–'68
Whitehead	Joshua Bartlett	1849–'50
		1851–'52
Williamsburg	Edwin Pitman	1863, '66
Williamsburg	E. Pitman	1867–'68
Wyndham	Samuel A. Eveleth	1849–'50
		1851–'56
MARYLAND.		
Agricult'l College, Prince George Co.	Montg. Johns, M. D.	1861–'62
Annapolis	Prof. W. F. Hopkins	1851
Annapolis	A. Zumbrock, M. D.	1855–'56
Annapolis	W. R. Goodman	1856–'68
Baltimore	Dr. Lewis F. Steiner	1852–'53
Baltimore	Prof. Alfred M. Mayer	1857–'59
Bladensburg	Benj. O. Lowndes	1854–'64
Catonsville	George S. Grape	1865–'67
Chestertown	James A. Pearce, jr	1855–'57
Chestertown	Prof. A. W. Clark	1858
Chestertown	Rev. A. Sutton	1859–'60
Chestertown	Prof. J. Russell Dutton.	1861–'64
Cumberland	T. C. Atkinson	1849
Ellicott's Mills	Philip Tabb	1864
Emmittsburg	Eli Smith	1866–'68
Emmittsburg	Prof. C. H. Jourdan	1867–'68
Frederick	Dr. Lewis F. Steiner	1851
Frederick	Henry E. Hanshew	1852–'54
		1856–'63
Frederick	Miss H. M. Baer	1865–'66
Hagerstown	Rev. J. P. Carter	1852, '54
Leitersburg	Lewis J. Bell	1852
Leitersburg	Jacob E. Bell	1858–'62
Leonardtown	Dr. Alex. McWilliams	1858–59
New Windsor	Prof. J. P. Nelson	1852
New Windsor	Prof. J. F. Maguire	1854
Nottingham	A. P. Dalrymple	1849
Oakland	L. R. Cofran	1857–'58
Port Deposit	Henry W. Thorp	1849
Ridge	T. G. Stagg	1856–'57
Sandy Hill	Isaac Bond	1849
Sykesville	Prof. William Baer	1849–'50
		1851–'52
Sykesville	Prof. Wm. Baer and Miss H. M. Baer.	1853–'54
Sykesville	Miss H. M. Baer	1855–'65
St. Inigoes	Rev. Jas. Stephenson	1859–'68
Union Bridge	Warrington Gillingham.	1864
Walkersville	Josiah Jones	1849–'51
Woodlawn	James O. McCormick	1865–'68
MASSACHUSETTS.		
Amherst	Prof. E. S. Snell	1849–'68
Baldwinsville	Rev. E. Dewhurst	1863–'65
Barnstable	B. R. Gifford	1852–'53

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
MASS.—Continued.		
Boston	E. L. Smith	1857
Boston	E. L. Adams.	1859
Bridgewater	Marshal Conant	1854
Bridgewater	L. A. Darling	1856–'57
Bridgewater	C. W. Felt and others	1858–'59
Bridgewater	Normal School	1860–'61
Brookline	Rev. John B. Perry	1868
Byfield	Martin N. Root	1851
Cambridge	* W. C. Bond	1855–'58
Cambridge	Harvard College Observatory.	1859–'60
Cambridge	Augustus Fendler	1865–'66
Canton	D. H. Ellis	1857–'58
Chelsea	Naval Hospital	1861–'64
Clinton	Geo. M. Morse, M. D	1860–'61
Danvers	A. W. Mack	1858–'59
Duxbury	James Ritchie	1849
Fall River	Charles C. Terry	1861
Fitchburg	George Raymond	1860–'61
Florida	L. F. Whitcomb	1857–'61
Framingham	Gustavus A. Hyde	1849
Georgetown	Henry M. Nelson	1865–'67
Georgetown	S. Augustus Nelson	1867–'68
Grafton	Rev. Wm. G. Scandlin.	1860–'61
Hinsdale	Rev. E. Dewhurst	1868
Kingston	Guilford S. Newcomb.	1866–'68
Lawrence	John Fallon	1857–'68
Lowell	Charles J. Gilliss	1849–'51
Lunenburg	Geo. A. Cunningham.	18[illegible]–'68
Lynn	Jacob Bachelder	1849–'50
		1851–'52
Mendon	Henry Rice	1849
Mendon	Dr. John G. Metcalf	1849–'68
Milton	Rev. A. K. Teele	1867–'68
Nantucket	Hon. Wm. Mitchell	1853–'61
New Bedford	Thomas Bailey	1819, '51
New Bedford	Samuel Rodman	1853–'68
New Bedford	Edward T. Tucker	1866–'67
Newbury	John H. Caldwell	1865–'68
Newburyport	Dr. H. C Perkins	1853–'58
North Attleboro'	Henry Rice	1851–'58
North Billerica	Rev. Elias Nason	1866–'68
Plainfield	Francis Shaw	1857
Princeton	Hon. John Brooks	1853–'57
Randolph	Orrin A. Reynolds	1861–'62
Richmond	William Bacon	1849–'50
		1851–'63
		1865–'68
Rockport	R. D. Mussey	1854
Roxbury	Benjamin Kent	1849
Sandwich	N. Barrows, M. D	1863–'65
South Groton	Alfred Collin	1859
Southwick	Amasa Holcomb	1849–'57
Springfield	Lucius C. Allin	1853–'56
Springfield	Francis A Brewer	1859
Stockbridge	Abraham S. Peet	1849
Taunton	Albert Schlegel	1854–'57
Topsfield	Nathan W. Brown	1860–'62
Topsfield	John H. Caldwell	1863–'64
Topsfield	Arthur M. Merriam	1864–'66
Topsfield	Sidney A. Merriam	1866–'68
Uxbridge	Dr. James Robbins	1854
West Dennis	Eugene Tappan	1864
Westfield	* Rev. Dr. E. Davis	1854–'66
West Newton	John H. Bixby	1867–'68
Weymouth	Dr. N. Q. Tirrell	1856–'57
		1859
Williamstown	C. M. Freeman	1851–'52
Williamstown	Prof. P. A. Chadbourne	1854
Williamstown	D. J. Holmes, Jas. Orton, Lavallette Wilson, and others.	1854–'57
Williamstown	I. McGee, C. J. Lyons, M. L. Berger & others.	1857–'59
Williamstown	Astronomical Obsev'y.	1860–'68
Williamstown	Prof. Albert Hopkins.	1868
Wood's Hole	B. R. Gifford	1854–'55
Worcester	S. F. Haven	1849–'52

Name of station.	Name of observer.	Years of observations.
MASS.—Continued.		
Worcester	Drs. Ed. A. Smith, F. H. Rice, and others.	1853–'56
		1865
Worcester	Dr. Geo. Chandler	1854
Worcester	John S. Sargent and others.	1857–'58
Worcester	Dr. H. C. Prentiss	1859–'64
Worcester	Joseph Draper, M. D.	1866–'68
MICHIGAN.		
Alpena	J. W. Paxton	1865–'68
Ann Arbor	Dr. H. R. Schetterly	1852
Ann Arbor	L. Woodruff	1852–'54
		1856–'57
Ann Arbor	Prof. A. Winchell	1854
		1856–'57
Ann Arbor	L. Woodruff and A. Winchell.	1855
Battle Creek	Dr. W. M. Campbell.	1849–'60
Brest	Dr. Thos. Whelpley.	1848–'54
Brooklyn	Dr. M. K. Taylor	1852–'54
Burr Oak	Charles Betts	1849–'52
Central Mine	S. H. Whittlesey	1867–'68
Clifton	Wm. Van Orden, jr	1862–'63
Clinton	Elmore Wainwright	1851–'52
Coldwater	N. C. Southworth	1868
Cooper	Mrs. Octavia C. Walker.	1854–'58
		1860–'62
Copper Falls	Chas. S. Whittlesey	1856–'57
Corunna	Heber Crane	1855
Detroit	Wm. A. Raymond	1849
Detroit	*Rev. Geo. Duffield	1849–'56
Detroit	Dr. Zena Pitcher and L. S. Horton.	1858–'60
Detroit	U. S. Engineers	1860–'63
Detroit	Dr. Zena Pitcher	1861–'62
Eagle River	Mrs. M. A. Goff	1856
East Saginaw	Dr. S. F. Mitchell	1854
Flint	Dr. D. Clark	1854–'55
Forestville	Lieut. C. N. Turnbull.	1858
Fort Gratiot	Lieut. C. N. Turnbull, U. S. A.	1858–'59
Garlick	Edwin Ellis, M. D	1864
Grand Haven	Heber Squier	1859–'63
Grand Rapids	Franklin Everett	1849
Grand Rapids	Dr. J. Hollister	1849–'51
Grand Rapids	Alfred O. Currier	1854–'58
Grand Rapids	L. H. Streng	1857–'60
Grand Rapids	Edwin A. Strong	1860–'61
Grand Rapids	J. B. Parker	1864
Grand Rapids	E. S. Holmes	1865–'68
Grand Traverse	H. R. Schetterly	1854
Holland	L. H. Streng	1860–'63
		1865–'68
Homestead	George E. Steele	1864–'67
Houghton	J. B. Minick	1865–'66
Howell	Dr. H. R. Schetterly	1849–'50
		1851–'52
Kalamazoo	Harmon M. Smith	1864–'67
Kalamazoo	Milton Chase	1865–'67
Kalamazoo	Frank Little	1868
Lake George	J. H. Foster and Edward Perrault	1859
		1859
Lansing	Cleveland Abbe	1859
Lansing	J. C. Holmes	1859
Lansing	Prof. R. C. Kedzie	1863–'68
Litchfield	R. Bullard	1865–'68
Lower Saginaw	James G. Birney	1819
Manchester	F. M. Reasner, M. D.	1861
Marquette	Peter White	1857
Marquette	Dr. G. H. Blaker, jr	1858–'61
Marquette	Dr. G. H. Blaker, jr., and F. M. Bacon.	1862–'63
Mill Point	Rev. L. M. S. Smith	1860–'62
Monroe	Thomas Whelpley	1852
Monroe	Capt. A. D. Perkins	1854
Monroe	Miss H. I. Whelpley	1855–'60
Monroe	G. W. Bowlsby	1859–'61

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
MICHIGAN—Con'd.		
Monroe	Miss Helen I. and Florence Whelpley.	1861
Monroe	Miss F. E. Whelpley	1862–'68
Monroe Piers	John Lane	1859–'63
Muskegon	H. A. Pattison	1868
New Buffalo	J. B. Crosby	1857–'62
Northport	H. R. Schetterley	1862–'63
Northport	Rev. Geo. N. Smith	1865–'68
Ontonagon	H. Selby	1859–'63
Ontonagon	Edwin Ellis, M. D	1865–'68
Ottawa Point	John Oliver	1859–'61
Otsego	Matthew Coffin	1859–'62
Otsego	Milton Chase	1861
Oshtemo & elsew'e	Henry H. Mapes	1864–'68
Pennsylvania Mine	Richard H. Griffith	1868
Pleasanton	Joseph D. Millard	1868
Pontiac	James A. Weeks	1864
Port Huron	James Allen, jr	1857–'59
Port Huron	Geo. A. Stockwell	1860
Redford Centre	Chas. C. Smith, M. D	1861
Romeo	Isaac Stone	1855
Romeo	Seth L. and G. P. Andrews.	1856
Romeo	S. L. Andrews, M. D	1855, '57
Saugatuck	L. H. Strong	1854–'56
St. James	James J. Strong	1853–'56
Sugar Island	U. S. Engineers	1863
Tawas City	U. S. Engineers	1861–'63
Thunder Bay	J. I. Malden	1859–'63
Ypsilanti	Miss G. Webb	1859
Ypsilanti	C. S. Woodward	1859–'63
MINNESOTA.		
Afton	Dr. B. F. Babcock	1865–'67
Beaver Bay	Thomas Clark	1858–'59
Beaver Bay	Henry Wieland	1859–'60
Beaver Bay	Thos. Clark and C. Wieland.	1860
Beaver Bay	C. Wieland	1861–'68
Bowles Creek	Andrew Stouffer	1865–'66
Buchanan	Stephen Walsh	1857–'58
Burlington	A. A. Hibbard	1858–'60
Cass Lake	Alonzo Barnard	1852
Cass Lake Mission	Rev. B. F. Odell	1856
Chatfield	T. F. Thickstun	1859–'61
Danville	Thomas A. Kellett	1868
Fond du Lac	Rev. Joseph W. Holt	1849–'51
Forest City	A. C. Smith	1859–'61
Forest City	Henry L. Smith	1862–'66
Fort Ripley	Rev. S. W. Mauncey	1854
Grand Portage	Richard Bardon	1867
Hastings	T. F. Thickstun	1861–'62
Hazelwood	S. R. Riggs	1855–'58
Hennepin county	J. B. Clough	1864–'65
Itasca	O. H. Kelley	1860–'61 1863
Lac qui Parle	Rev. S. L. Riggs	1852–'53
Lac qui Parle	S. R. and A. L. Riggs	1854
Lake Winnibigoshish.	Rev. Benj. F. Odell	1859
Lapham	E. M. Wright	1857
Lapham	J. F. McMullen and D. F. Shortwell.	1858
Lapham	Samuel Locke	1858
Mankato	Wm. Kilgore	1864
Minneapolis	Wm. Cheney	1864–'68
New Ulm	Charles Roos	1864–'68
Pajutazee	Rev. S. R. Riggs	1859–'62
Pembina	Charles Cavileer	1852
Princeton	O. E. Garrison	1856–'60
Princeton	S. M. Byers	1860
Red Lake	Rev. E. W. Carver	1853–'54
Red Wing	Rev. Jabez Brooks	1856
Red Wing	Prof. A. M. Stephens	1867
Sandy Lake	Samuel Spates	1852
Sauk Centre	Smith Bloomfield	1868
Sibley	C. W. Woodbury	1865–'67
Sibley	C. W. and C. E. Wood-	1868
MINNESOTA—Co'd.		
Smithfield	B. C. Livings	1868
Stillwater	A. Van Voorhies	1858
St. Anthony's Falls.	C. F. Anderson	1854
St. Cloud	O. E. Garrison	1861–'62
St. Joseph's	Rev. D. B. Spencer	1853–'55
St. Joseph's	A. O. Keilum	1854
St. Paul	Rev. A. B. Paterson, D. D.	1862–'68
St. Paul	John W. Heimstreet-bury.	1866–'67
Tamarack	Mary A. Grave	1863–'64
Travers des Sioux	Rev. R. Hopkins	1849–'51
Wabashaw	Spencer L. Hillier	1857–'58
MISSISSIPPI.		
Brook Haven	T. J. R. Keenan	1867–'68
Columbus	James S. Lull	1855–'59
Como	E. W. Beckwith	1849
Fayette	Rev. T. H. Cleland	1866–'67
Gainesville	Charles A. Folsom	1849
Garlandsville	Rev. E. S. Robinson	1853–'55
Granville	James H. Vincent	1849
Grenada	Wm. Henry Waddell	1854
Grenada	Prof. Albert Moore	1859–'60 1866–'68
Hernando	Wm. M. Johnston	1859–'60
Jackson	Thomas Oakley	1849–'52
Jackson	A. R. Green	1851
Kingston	J. Edward Smith	1866–'67
Marion	T. W. Florer, M. D	1868
McLeod's	David Moore	1849
Monticello	J. R. Cribbs	1860–'61
Natchez	Geo. L. C. Davis	1849–'51
Natchez	J. Edward Smith	1856
Natchez	*R. McCary	1858–'61 1864–'66
Natchez	W. McCary	1866–'68
Oxford	Prof. L. Harper	1854–'56
Pass Christian	Rev. J. A. Sheppard	1860
Paulding	Rev. E. S. Robinson	1858–'59
Port Gibson	Prof. J. Boyd Elliott	1855–'57
Prairie Line	Rev. E. S. Robinson	1859–'61
Vicksburg	A. L. Hatch	1849–'52
Westville	J. R. Cribbs	1859–'60
Yazoo City	Col. C. B. Swasey	1860–'61
MISSOURI.		
Allenton	Aug. Fendler	1865–'68
Athens	John T. Caldwell	1864–'66
Augustus	Conrad Mallinckrodt	1859
Bethany	D. J. Heaston	1859–'60
Bolivar	W. J. Vankirk	1859–'61
Bolivar	James A. Race	1868
Booneville	Norris Sutherland	1859–'61
Canton	George P. Ray	1861–'68
Canton	Dr. J. M. Parker	1868
Cape Girardeau	Rev. James Knoud	1856–'58
Carrollton	John Campbell	1859
Carrollton	S. J. Huffaker	1859
Carrollton	D. J. Kirby	1860
Cassville	M. L. Wyrick	1859–'61
Charleston	George Whitcomb	1868
Dry Ridge	O. H. P. Lear	1854–'55
Dundee	S. S. Bailey	1859–'61
Easton	P. B. Sibley	1864–'66
Edinburg	John E. Vertrees	1866–'67
Edina	J. C. Agnew	1859–'66
Emerson	W. B. Kizer	1859
Farmington	Nathan P. Force	1859
Fort Pierre	Fred. Behmer	1854
Greenfield	S. B. Bowles, M. D	1859–'62
Greenville	O. D. Dalton	1859–'60
Hannibal	O. H. P. Lear	1853
Hannibal	Edw'd Duffield, M. D	1855–'56
Harrisonville	John Christian	1859–'68
Hematite	John M. Smith	1868
Hermann	Philip Weber	1859–'60

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
MISSOURI—Cont'd.		
Hermitage	Miss Belle Moore	1867–'68
Hornersville	W. H. Horner	1859–'61
Jefferson City	Nicolas De Wyl	1868
Kirksville	Robert Byers, M. D.	1859
Kirksville	J. H. Myers	1859–'63
Laborville	William Muir	1863–'64
Lancaster	John M. Weatherford	1859
Lexington	Joseph A. Wilson	1859
Lexington	Geo. W. Wilson, jr	1860
Lexington	P. S. Wilson	1861
Luray	B. P. Hanan	1859–'61
Oregon	William Kaucher	1867–'68
Paris	W. F. Maxey	1859–'62
Rhineland	Charles Vogel	1859–'60
Richmond	R. W. Finley	1859–'60
Rockport	C. Q. Chandler, M. D.	1855–'56
Rolla	Homer Ruggles	1867–'68
Springfield	J. A. Stephens	1857–'58
St. Joseph	Edward B. Neely	1857–'58
St. Louis	Dr. Geo. Engelmann	1853–'57 1859–'67
St. Louis	A. Wislizenus, M. D.	1856–'57
St. Louis	G. Engelman, M. D., and A. Wislizenus, M. D.	1858
St. Louis	Augustus Fendler	1859–'64
St. Louis	*J. H. Lunemann	1860–'62 1861
St. Louis	Rev. P. W. Koning	1861
St. Louis	Rev. F. H. Stuntebeck	1865–'68
St. Louis	Rev. I. Straetmans	1868
Stockton	Wm. Wells	1859–'61
Toronto	B. D. Dodson	1859–'60
Trenton	Thomas J. Conkling	1859
Tuscumbia	Wm. M. Lumpkin	1859
Union	Dr. W. Moore	1866
Union	Miss Belle Moore	1867
Warrensburg	Rev. J. E. Pollock	1868
Warrenton	Marion F. Hamaker	1859
Warrenton	Mary A. Tidswell	1859–'63
Waynesville	B. G. Lingow	1859
Westport	Rev. N. Scarritt	1851
MONTANA.		
Benton City	* Dr. H. M. Lehman	1868
Camp Cooke	* Dr. H. M. Lehman	1867
Cantonment Wright	T. Koleski	1861–'62
Helena City	Alex. Camp Wheaton	1866–'68
NEBRASKA.		
Bellevue	D. E. Reed	1854
Bellevue	Rev. Wm. Hamilton	1857–'67
Bellevue	Henry M. Burt	1857
Bellevue	Miss E. E. Caldwell	1868
Blackbird Hills	Rev. Wm. Hamilton	1867–'68
Brownville	Charles B. Smith	1858–'60
Dakota City	H. H. Brown	1867–'68
Deer Creek	Major Thos. S. Twiss	1859
De Soto	Charles Seltz	1867–'68
Elkhorn City	Anna M. J. Bowen	1858–'61
Elkhorn City	John S. Bowen	1865–'68
Fontanelle	John Evans	1859 1862–'63
Fontanelle	Henry Gibson	1868
Fort Pierre	M. C. Rosseau	1860–'61
Fort Union	E. T. Denig	1854
Glendale	A. L. Child, M. D.	1861 1866–'67
Glendale	Dr. A. C. Child and Miss J. E. Child.	1868
Jonin	L. J. Hill	1865
Kenosha	Bela White	1859–'62
Nebraska City	Edgar E. Mason	1859
Nebraska City	P. Zahner	1868
Nursery Hill	R. O. Thompson	1865
Omaha	Wm. N. Byers	1857–'59
Omaha	John G. Bain	1859–'60
NEBRASKA—Con'd.		
Omaha	James P. Allan	1860–'61
Omaha	C. B. Wells	1868
Peru	J. M. McKenzie	1867
Rock Bluffs	H. C. Pardee	1860–'61
South Pass wagon road expedition.	C. H. Miller	1859–'60
NEVADA.		
Star City	R. C. Johnson	1865
NEW HAMPSHIRE.		
Antrim	Rev. Wm. Hurlin	1866–'68
Claremont	F. N. Freeman	1857–'58
Claremont	Arthur Chase	1859–'68
Claremont	* Stephen O. Mead	1864–'67
Claremont	Linus Stevens	1867–'68
Concord	Dr. Wm. Prescott	1849–'57
Concord	H. E. Sawyer	1857–'58
Concord	E. P. Colby	1858
Concord	John T. Wheeler	1865–'68
Concord	James C. Knox	1868
Dublin	Rev. L. W. Leonard	1849 1851–'52
Dunbarton	Alfred Colby	1868
Exeter	Rev. L. W. Leonard	1853–'55
Exeter	Rev. Elias Nason	1861–'65
Farmington	Louis Bell	1860–'61
Francestown	Dr. Martin N. Root	1857
Francestown	A. H. Bixby	1857–'58
Great Falls	Henry E. Sawyer	1854–'57
Hanover	Prof. Ira Young and A. A. Young.	1853–'54
Isle of Shoals	Thos. B. Laighton	1849
Laconia Lake Village	J. W. French, agt. L. W. C. & W. M. Co.	1857–'61
Littleton	Robert C. Whiting	1863–'64
Londonderry	Robert C. Mack	1849–'57
London Ridge	Isaac S. French, M. D.	1862–'65
Manchester	Hon. S. N. Bell	1852–'57 1859–'61
North Barnstead	R. F. Hanscom	1855–'58
North Barnstead	Charles H. Pitman	1860–'68
North Littleton	Rufus Smith	1859–'60 1863–'64
Portsmouth	Dr. C. Chase, U. S. N.	1849
Portsmouth	John Hatch	1867–'68
Salmon Falls	George B. Sawyer	1853–'54 1856
Shelbourne	Fletcher Odell	1856–'68
Stratford	B. Gould Brown	1855–'58
Stratham	Andrew Wiggins	1859–'60
Stratford	Branch Brown	1859–'68
Tamworth	Alfred Brewster	18[illegible]7
Top of Mt. Washington.	Joseph H. Hall	1859
Wentworth	Peter L. Hoyt	1859
West Enfield	Nath. Purmort	1856–'58
NEW JERSEY.		
Belleville	Thos. B. Merrick	1849
Bloomfield	R. L. Cooke	1849–'58 1862–'63
Burlington	Prof. Adolph Frost	1849–'54
Burlington	Dr. E. R. Schmidt	1855 1857–'58
Burlington	Prof. A. Frost and Dr. E. R. Schmidt.	1856
Burlington	John C. Deacon	1863–'68
Cinnaminson	William Parry	1859–'60
Cole's Landing	James S. Lippincott	1864–'66
Dover	Howard Shriver	1866–'68
Elwood	J. S. Fritts	1867–'68
Freehold	B. F. Simpson and O. R. Willis.	1857–'58
Freehold	O. R. Willis	1859–'62
Greenwich	Benj. Sheppard	1856–'61

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
N. JERSEY—Con'd.		
Greenwich	Clarkson Sheppard	1864
Greenwich	C. Sheppard and Miss R. C. Sheppard.	1865–'67
Greenwich	Miss R. C. Sheppard	1868
Haddonfield	John Clement, jr	1849
Haddonfield	Samuel Wood	1866–'68
Lambertville	Jacob S. Gary	1849
Long Branch	Howard A. Stokes	1861, '63
Long Branch	Arch. Alexander	1865
Morristown	Dr. S. C. Thornton	1849, '61
Morristown	Miss E. E. Thornton	1859
Morristown	Thos. J. Beans	1865–'68
Morristown	Jos. W. Lippincott	1865
Mount Holly	Morgan J. Rhees, M.D	1861–'68
Newark	W. A. Whitehead	1849–'68
New Brunswick	Prof. Geo. H. Cook	1854 1865–'68
New Brunswick	E. T. Mack	1854
New Brunswick	Edwin Allen	1859
New Brunswick	Edwin Allen and G. W. Thompson.	1860
New Brunswick	Geo. W. Thompson	1861–'65
Newfield	E. D. Couch	1867–'68
New Germantown	Arthur B. Noll	1868
Newton	Thos. Ryerson, M. D	1868
Passaic Valley	Wm. Brooks	1863–'65
Paterson	Wm. Brooks	1866–'68
Progress	Thos. J. Beans	1863–'65
Readington	John Fleming	1866–'67
Riceville	Prof. L. Harper	1860–'61
Rio Grande	Jerusha R. Palmer	1868
Salem	C. M. Dodd	1856
Salem	George Watson	1859
Seaville	Barker Cole	1865–'67
Seaville	E. C. Cole	1868
Sergeantsville	John T. Sergeant	1857–'58
Trenton	Ephraim R. Cook	1865–'68
Vineland	Jno. Ingram, M. D	1867–'68
Woodstown	George Watson	1860
NEW MEXICO.		
Pope's Expedition	James M. Reade	1855–'57
NEW YORK.		
Adam's Centre	C. D. Potter, M. D	1859–'61
Albany	H. M. Paine, M. D	1865–'66
Albion	L. F. Munger	1849–'54
Alps	James H Ball	1849–'51
Angelica	E. M. Alba	1854–'58
Auburn	John B. Dill	1860–'65
Baldwinsville	John Bowman	1849–'67
Beaver Brook	C. S. Woodward	1853–'54
Bellport	H. W. Titus	1857–'62
Beverley	Thos. B. Arden	1853–'59
Blackwell's Island, N. Y.	W. W. Sanger, M. D.	1855–'57
Brookhaven	E. A. Smith and daughters.	1868
Buffalo	A. Hesmer	1849–'52
Buffalo	Elias O. Salisbury	1853–'54 1860
Buffalo	Dr. S. B. Hunt	1854
Buffalo	W. D. Allen	1854
Buffalo	William Ives	1858–'62 1866–'68
Buffalo	U. S. Engineers	1860–'63
Canton	E. W. Johnson	1853–'58
Cazenovia	Prof. Aaron White	1856–'64
Cazenovia	Prof. Wm. Soule	1865, '67 1868
Charlotte	Andrew Mulligan	1859–'63
Chatham	Cornelius Chase	1849–'51
Chatham	C. Thornton Chase	1853–'54
Clinton	Prof O Root	1856
Clinton	H. M. Paine, M. D	1857–'59 1862–'65
Clockville	J. P. Chapman	1849
N. YORK—Con'd.		
Clyde	Matthew Mackie	1859–'62
Constableville	L. L. Fairchild	1852
Constantia	Sereno Clark	1861
Dansville	Rev. John J. Brown	1859–'61
Depauville	Henry Hass	1865–'68
East Franklin	Dr. J. W. Smith	1854
East Henrietta	A. S. Wadsworth	1859 '62
Eden	Stephen Landon	1855
Eden	Anna S. Landon	1857–'59
Falconer	Laurens A. Langdon	1853–'54
Farmer	A. B. Covert	1859
Farmingdale	John C. Merritt	1868
Fishkill Landing	* W. H. Denning	1855–'66
Flatbush	Rev. Thos. H. Strong	1854–'55
Flatbush	Rev. R. D. Van Kleck	1856–'60
Flatbush	Rev. W. W. Howard	1860
Flatbush	Rev. E. T. Mack	1862–'68
Fordham	John Aubier	1856
Fordham	Claudius Pernot	1856–'57
Fordham	H. M. Paine, M. D	1858
Fordham	Rev. Jno. Aubier and Prof. A. T. Monroe.	1859–'62 1864
Fort Ann	P. A. McMore	1863–'66
Fort Edward	Prof. Solomon Sias	1857–'59
Fort Niagara	L. Leffman	1859–'63
Fredonia	Prof. D. J. Pratt	1854, '63 1864
Friendship	George W. Fries	1866–'67
Garrisons	Thos. B. Arden	1860–'61 1863–'68
Geneva	Rev. W. D. Wilson	1855–'57 1864–'68
Geneva	Job Elleston	1859
Germantown	Wm. Tompkins	1859
Germantown	Rev. Sanford W. Roe	1866–'68
Gouverneur	Dr. P. O. Williams	1852–'54
Gouverneur	Cyrus H. Russell	1860–'68
Glen's Falls	Warren P. Adams	1854
Great Valley	Kathalo Kelsey	1859–'60
Havana	Col. E. C. Frost	1859–'60
Hector	David Trowbridge	1865–'67
Hermitage	A. A. Hibbard	1860–'62
Homer	Edwin C. Reed	1855–'57
Houseville	Walter D. Yale	1849–'54 1856–'60 1865–'68
Inst. for Deaf and Dumb, N. Y.	Prof. Oran W. Morris	1849–'68
Ilion	J. D. Ingersoll	1859–'60
Jamestown	Rev. Sanford W. Roe	1863–'66
Jericho, L. I	Albert G. Carll	1849
Lake	Peter Ried	1856–'58
Leroy	L. F. Munger	1854
Leyden	C. C. Merriam	1868
Liberty	John Felt	1855–'56
Lima	Prof. S. A. Lattimore	1861
Little Genesee	Daniel Edwards	1866–'68
Lockport	E. Giddings	1849
Lockport	James B. Trevor	1849–'52
Lodi	* John Lefferts	1849–'58
Lowville	Irah R. Adams	1854
Lowville	J. Caroll House	1854–'58
Lyons	Dr. E. W. Sylvester	1859–'62
Madrid	E. A. Dayton	1849–'59
Marathon	Lewis Swift	1863
McGrawville	J. Metcalf Smith	1856–'57
Mexico	John R. French	1855–'57
Minaville	D. S. Bussing and J. W. Bussing.	1867
Minaville	J. W. Bussing	1868
Mohawk	James Lewis	1861–'68
Morristown	William Day	1859
Moriches	E. A. Smith and Miss N. Smith.	1864–'67
Morley	Ezra Parmelee	1849
Newark Valley	Rev. Samuel Johnson	1868
Newburg	James H. Gardiner	1864–'68
New York	U. S. Naval Station	1849
New York	J. S. Gibbons	1854

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
N. YORK—Con'd.		
New York	S. De Witt Bloodgood	1854–'55
New York, (Eastern Dispensary.)	Caleb Swann and Dr. J. P. Loines.	1854–'61
New York	Fred. I. Slade	1860–'61
New York, (Rutherford's Observatory.)	Charles C. Wakely	1860–'63
New York	Naval hospital	1860–'68
New York, (N. Y. Skating Club.)	E. B. Cook	1863–'66
New York	Rev John M. Aubier	1865–'67
New York, (Columbia College.)	Prof. Chas. A. Joy	1865–'68
New York, (Central Park Observatory.)	Haden Patrick Smith	1867–'68
North Argyle	Geo. M. Hunt	1864
North Hammond	Charles A. Wooster	1866–'68
North Salem	John F. Jenkins	1849–'53
North Salem	Mrs. M. J. Lobdell	1855–'56
North Volney	J. M. Partrick	1868
Nichols	R. Howell	1857–'68
Ogdensburg	W. E. Guest	1849–'52 1854–'63
Oneida	Dr. Stillman Spooner	1864–'68
Oswego	C. Strong	1849
Oswego	J. H. Hart	1851–'54
Oswego	Capt. W. S. Malcolm	1854–'68
Otto	Prof. Weston Flint	1861
Ovid	J. W. Chickering	1855–'58
Palisades	W. S. Gilman, jr	1868
Palmyra	Stephen Hyde	1864–'65
Peekskill	Charles A. Lee	1854
Penn Yan	Dr. H. P. Sartwell	1854–'57 1859
Perry City	David Trowbridge	1864
Philipstown	Thos. B. Arden	1851–'52
Pine Hill	Godfrey Zimmerman	1859–'60
Plainville	J. H. Norton	1856–'57
Plattsburg	Joseph W. Taylor	1855–'57
Pompey	S. Marshall Ingalls	1857–'58
Pompey Hill	John F. Kendall	1856
Poughkeepsie	Prof. C. B. Waring	1849
Rochester	Prof. Wetherell	1849
Rochester	* Prof. C. Dewey	1855–'67
Rochester	*Prof. M. M Matthews	1859–'67
Rochester	H. Wells Mathews	1868
Rochester	W. M. L. Fisk	1868
Sackett's Harbor	U. S. Naval Station	1849
Sackett's Harbor	Mandrin Linus	1851–'52
Sackett's Harbor	H. Metcalf	1859–'63
Sag Harbor	E. N. Byram	1849–'58
Saratoga	Walter H. Riker	1856–'59
Saugerties	R. G. Williams	1863–'66
Saugerties	Jas. W. Grush, Jas. M. Alexander, and Levi S. Packard.	1859–'60
Schenectady	Robert M. Fuller and Haven V. Swart.	1864
Schenectady	Alexis A. Julien and H. A. Schauber.	1858–'59
Seneca Falls	Elisha Foote	1849
Seneca Falls	John P. Fairchild	1849–'52
Seneca Falls	Chas. A. Avery	1853–'54
Seneca Falls	Philo Cowing	1861–'64
Sennett	Henry B. Fellows	1857
Sherburne	Rev. Jas. R. Haswell	1865
Sing Sing	C. F. Maurice	1849–'52
Skaneateles	W. M. Beauchamp	1860–'67
Sloansville	G. W. Potter	1868
Smithville	J. Everett Breed	1849–'52 1854–'56
Somerville	Dr. F. B. Hough	1849–'51
South Edmeston	L. A. Beardsley	1849–'51
South Hartford	Grenville M. Ingalsbee.	1863–'68
South Trenton	Capt. Storrs Barrows	1863–'68
Spencertown	A. W. Morehouse	1855–'57
Spencertown	Irving Magee	1858

Name of station.	Name of observer.	Years of observations.
N. YORK—Con'd.		
Spencertown	Levi S. Packard	1861
Springville	J. W. Earle	1849
Springville	Moses Lane	1851
Stapleton	Spencer L. Hillier	1867–'68
Suffern	James H. Warren	1863
Syracuse	Henry L. Dinsmore	1851–'52
Theresa	S. O. Gregory	1861–'68
Throg's Neck	Francis M. Rogers	1864, '66
Throg's Neck	Miss Elizabeth Morris	1865–'68
Troy	John W. Heimstreet	1849–'68
Troy	Prof. E. A. H. Allen	1853–'54
Troy	Prof. Dascom Greene	1856–'57
Troy	Wm. L. Haskin	1860–'61
Utica	Dr. L. A. Tourtellot	1856–'57 1868
Utica	Joseph Graham	1860
Vermillion	E. B. Bartlett	1860–'68
Wales	S. O Carpenter	1851
Wampsville	Dr. Stillman Spooner	1853–'63
Warsaw	J. P. Morse	1865
Waterburgh	David Trowbridge	1868
Waterford	John C. House	1856–'63
Watertown	Dr. P. O. Williams	1855–'57
Waterville	James M. Tower	1849–'51
Wellsville	H. M. Sheerer	1857–'58 1860
West Concord	Lewis Woodward	1856–'57
West Day	Jude M. Young	1858–'59
West Farms	J. S. Gorton	1856–'57
West Morrisania	I. Zaepffel	1857–'59
White Plains	O. R. Willis	1862–'68
Wilson	E. S. Holmes	1858–'64
NORTH CAROLINA.		
Asheville	W. W. McDowell	1857–'58
Asheville	E. J. Aston	1867–'68
Asheville	J. F. E. Hardy, M. D.	1868
Attaway Hill	F. J. Koon	1849–'62 1867–'68
Chapel Hill	Prof. James Phillips	1849–'61
Davidson College	Prof. W. C. Kerr	1858–'59
Gaston	Geo. F. Moore, M. D	1856–'58
Goldsborough	Prof. D. Morelle	1855–'58
Greensboro'	Geo. F. Moore, M. D.	1859–'61
Goldsborough	Prof. E. W. Adams	1860–'61 1868
Green Plains	Sam'l W. Westbrook	1859
Guilford Mine	Alexander Wray	1867
Jackson	Rev. Fred. Fitzgerald	1852–'54
Kenansville	Prof. N. B. Webster	1868
Lake Scuppernong	Rev. J. A. Sheppard	1849–'52
Lake Scuppernong	D. Morrell	1851
Lincolnton	Dr. J. Bryant Smith	1854
Marlboro'	Robert H. Drysdale	1858
Murfreesboro'	Rev. A. McDowell	1856–'61
Oxford	John H. Mills	1866–'67
Oxford	Wm. R. Hicks, M. D	1867–'68
Raleigh	T. Carter and W. H. Hamilton.	1859
Raleigh	W. H. Hamilton	1860
Raleigh	Rev. Fisk P. Brewer	1866–'68
Rutherfordtown	J. W. Calloway	1849
Statesville	Thos. A. Allison	1866–'68
Thornbury	Rev. F. Fitzgerald	1854
Thornbury	Dan. Morelle	1854
Trinity College,	Rev. B. Craven	1860–'61
Warrenton	Dr. W. M. Johnson	1857–'58
Wilson	E. W. Adams	1866
OHIO.		
Andrews	Dr. W. W. Spratt	1860–'61
Athens	Prof. W. W. Mather	1849–'51
Austinburg	J. G. Dole and C. S. S. Griffing.	1862–'63
Austinburg	David S. Alvord	1864
Austinburg	J. G. Dole	1864
Austinburg	E. D. Winchester	1864–'66

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
OHIO—Continued.		
Avon	Rev. L. F. Ward	1858–'60
Bellecentre	Rev. R. Shields and J. C. Smith.	1857–'59
Bellecentre	Rev. Robert Shields	1854 1860–'61
Bellefontaine	Joseph Shaw	1855–'60
Berea	Prof. G. M. Barber	1854
Bethel	George W. Crane	1859–'68
Bowling Green	W. R. Peck, M. D	1857–'63
Bowling Green	John Clarke	1866–'68
Breckville	Rev. S. L. Hillier	1859–'61
Cardington	Hubert A. Schauber	1863
Centralia	Hubert A. Schauber	1864–'66
Cheviot	Ebenezer Hannaford	1855–'57
Cincinnati	John Lea	1849
Cincinnati	F. W. Hurtt	1854 1857–'58
Cincinnati	Geo. W. Harper	1855–'68
Cincinnati	A. A. Warder	1859–'63
Cincinnati	R. C. & J. H. Phillips	1859–'64
Cincinnati	Eli T. Tappan	1860–'62
Cincinnati	R. C. Phillips	1865–'68
Cleveland	Gustavus A. Hyde	1851 1855–'61 1868
Cleveland	Edward Wade	1852
Cleveland	Edward Colburn	1858–'63
Cleveland	U. S. Engineers	1860–'63
Cleveland	G. A. Hyde and Mrs. Hyde.	1862–'67
Cleveland	T. A. Smurr	1866–'68
College Hill	G. S. Ormsby	1854
College Hill	Prof. R. S. Bosworth	1853–'57
College Hill	Prof. J. H. Wilson	1858–'65
College Hill	J. W. Hammitt	1859–'68
College Hill	L. B. Tuckerman	1865–'67
Collingwood	Henry Bennett	1856–'57
Collingwood	Sarah E. Bennett	1858
Coshocton	Thos. H. Johnson	1861–'62
Columbus	Theo. G. Wormley	1851, '52
Croton	Mark Sperry	1860
Croton	Rev. E. Thompson and Mark Sperry.	1861
Croton	Rev. Elias Thompson.	1862–'63
Cuyahoga Falls	D. M. Rankin	1864–'65
Dallasburg	F. G. Hill	1859–'63
Dayton	Cooper Female Seminary.	1856
Dayton	Jas. C. Fischer, M. D	1856
Dayton	Lewis Groneweg	1858
East Cleveland	Mrs. M. A. Pillsbury	1861–'62
East Fairfield	S. B. McMillan	1859–'67
East Rockport	Dr. J. P. Kirtland	1854
Eaton	Thomas J. Larsh	1863–'65
Edinburg	Smith Sanford	1857–'58
Franklin	W. L. Schenck, M. D.	1855–'57
Freedom	H. M. Davidson	1859–'60
Freedom	H. M. Davidson and Wilson Davidson.	1861
Freedom	Wilson Davidson	1862
Gallipolis	G. W. Livesay	1854–'56
Gallipolis	A. P. Rogers	1857–'58 1864–'68
Garrettsville	Warren Pierce	1861–'63
Germantown	L. Groneweg	1852–'56
Germantown	J. S. Binkerd	1856–'57
Granville	Prof. P. Carter	1849
Granville	Dr. S. N. Sanford	1849–'58
Harmar	W. G. Fuller	1860–'61
Hillsborough	Rev. J. McD. Mathews.	1851–'60 1863–'68
Hillsborough	C. C. James	1857
Hillsborough	Dr. C. C. Samms	1863
Hiram	S. L. Hillier and S. M. Luther.	1855
Hiram	Spencer L. Hillier	1856
Hiram	S. M. Luther	1856–'60
Hocking Port	Dr. John Rhoades	1859–'60
Homer	Thos. F. Withrow	1852
OHIO—Continued.		
Hudson	Prof. C. A. Young and E. W. Childs.	1858–'59
Hudson	Prof. C. A. Young and A. C. Barrows.	1860–'61
Hudson	Prof. C. A. Young. E. W. Stuart. J. C. Elliot. W. Pettingill. H. R. Watterson.	1862
Hudson	Prof. C. A. Young and J. C. Elliot.	1863
Huron	Edmund W. West	1854
Iberia	S. T. Boyd	1859
Jackson	Geo. L. Crookham	1849–'54
Jackson	G. L. Crookham and M. Gilmore.	1855
Jackson	S. B. Wood	1855
Jackson	M. Gilmore	1857–'58
Jacksonburgh	J. B. Owsley, M. D.	1868
Jefferson	James D. Herrick	1855–'58
Keene	Dr. E. C. Bidwell	1849–'52
Keene	E. Spooner	1853–'54
Kenton	C. H. Smith, M. D.	1862–'63 1866–'68
Kelly's Island	Geo. C. Huntingdon	1859–'68
Kingston	Prof. Jno. Haywood	1863–'67
Lafayette	Samuel Knoble	1867
Lancaster	Lewis M. Dayton	1857
Lancaster	H. W. Jaeger	1858
Lancaster	W. E. Davis	1859
Lancaster	J. W. Towson	1866
Lebanon	Joseph C. Hatfield	1849
Little Hocking	James Fraser	1862–'63
Little Mountain	E. J. Ferriss	1867–'68
Madison	Rev. L. S. Atkins	1857–'60
Madison	Mrs. Ardelia C. King	1859–'63
Mansfield	F. A. Benton	1851–'52
Marietta	D. P. Adams	186[illegible]–'63
Marietta	Prof. J. W. Andrews	1849–'55
Marion	H. A. True	1865–'68
Marion	T. Chase	1859
Martin's Ferry	Charles R. Shreve	1867
Medina	Rev. L. F. Ward	1857–'58
Medina	Wm. P. Clarke	1858–'63
Middlebury	Michael Beecher	1849
Milnersville	Rev. D. Thompson	1862–'68
Monroe county	Enoch D. Johnson	1859
Mount Auburn	Senior class Mt. Auburn Female Inst.	1868
Mt. Pleasant	David H. Tweedy	1859–'60
Mount Tabor	William Lapham	1849
Mount Union	Newton Anthony	1857–'60
Mount Vernon	F. A. Benton	1853–'55
Mount Victory	W. C. Hampton	1859–'60
Newark	Lewis M. Dayton	1854–'55
Newark	Isaac Dille	1859–'63
New Concord	Prof. S. G. Irvine	1849
New Lisbon	J. F. Benner	1857–'68
New Westfield	A. E. Jerome	1862–'63
North Bend	R. B. Warder	1868
North Fairfield	O. Burras	1867–'68
Northwood	Prof. J. R. W. Sloane	1852
Norton	W. D. Watkins	1849
Norwalk	G. A. Hyde	1854
Norwalk	Rev. Alfred Newton	1861–'68
Oberlin	Profs. Fairchild and Dascomb.	1849–'50
Oberlin	Prof. J. N. Allen	1851–'52 1857
Oberlin	Prof. J. H. Fairchild	1853–'56
Oberlin	Frederick Allen	1860
Perrysburg	F. Hollenbeck	1854–'56 1858
Perrysburg	F. and D. K. Hollenbeck.	1857
Portsmouth	James H. Poe	1855–'58
Portsmouth	D. B. Cotton, M. D	1859–'63
Portsmouth	Lud. Engelbrecht	1863–'65
Republic	Stephen S. Dorsey	1851
Richmond	Jacob N. Desellem	1854–'55

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.	Name of station.	Name of observer.	Years of observations.
OHIO—Continued.			PENN.—Continued.		
Ripley	J. Ammen	1857–'61	Byberry	John W. Saurman	1860–'61
Ripley	Dr. G. Bamback	1864–'67	Byberry	Isaac C. Martindale	1861–'67
Ripley	Mrs. M. M. Marsh	1867–'68	Canonsburg	Prof. J. R. Williams	1849
Russell Station	J. W. Gamble	1859–'60	Canonsburg	F. L. Stewart	1849
Sandusky	Thomas Niell	1859–'68	Canonsburg	Rev. Wm. Smith, D. D	1855–'61
Savannah	Dr. John Ingram	1854–'63			1863–'68
Saybrook	Rev. L. S. Aikins	1862–'63	Canonsburg	Charles Davis	1860
Saybrook	James B. Fraser	1864–'66	Canonsburg	Lyceum Jefferson Col.	1861–'63
Seville	Rev. L. F. Ward	1861–'62	Carlisle	Prof. S. F. Baird	1849
Sharonville	Wm F. Bowen	1859–'60	Carlisle	Prof. W. C. Wilson	1855–'59
Sidney	Joseph Shaw	1857	Carlisle	W. H. Cook	1868
Smithfield	D. H. Tweedy	1866	Carpenter	E. L. McNett	1862
Smithville	John H. Myers	1864–'66	Ceres	R. P. Stevens	1849–'54
Smithville	Wm. Hoover	1868	Chambersburg	Wm. Heyser, jr	1858–'62
Steubenville	Roswell Marsh	1849–'63	Chromedale	Joseph Edwards	1854–'57
Steubenville	J. B. Doyle	1865–'68	Chromedale	Joseph Edwards and John H. Smedley.	1858
Springfield	Samuel C. Frey	1859–'61			
Toledo	Sarah E. Bennett	1859	Clarksburg	Barnet McElroy	1852
Toledo	E. B. Raffensperger	1859	Connellsville	John Taylor	1849–'68
Toledo	J. B. Trembley, M. D	1860–'68	Darby	John Jackson	1849–'52
Troy	Charles L. McClung	1859–'63	Dyberry	Theodore Day	1865–'68
Twinsburg	N. A. Chapman	1860	Easton	A. R. McCoy	1849
Unionville	Miss A. Cunningham	1854–'57	Easton	Prof. J. H. Coffin	1851
Unionville	Mrs. Ardelia C. King	1858	Easton	E. L. Dodder	1851
Urbana	Prof. M. G. Williams	1855–'68	Easton	Selden J. Coffin	1857–'58
West Bedford	H. D. McCarty	1856–'57	Easton	Selden J. Coffin and G. S. Houghton.	1859–'60
Welchfield	B. F. Abell	1857–'66			
Wellington	Rev. L. F. Ward	1863	Easton	Geo. S. Houghton	1861
Westerville	Prof. Jno. Haywood	1858–'62	East Smithfield	James E. Tracy	1859
		1868	Erie	Benjamin Grant	1849
Westerville	Prof. H. A. Thompson	1863–'67	Ephrata	W. H. Spera	1865–'68
Western Star	A. S. Stuver	1861	Fallsington	Ebenezer Hance	1865–'68
West Union	Rev. Wm. Lumsden	1860–'61	Franklin	Rev. M. A. Tolman	1867–'68
Wooster	Eugene Pardee	1849	Freeport	Dr. A. Alter	1849
Wooster	Martin Winger	1864–'68	Freeport	Andrew Roulston	1849–'51
Williamsport	John R. Wilkinson	1867–'68	Freeport	A. D. Wier	1854
Windham	Samuel W. Treat	1857–'59	Freeport	John H. Baird	1860
Yankeetown	A. Jacque	1854	Fleming	Samuel Brugger	1856–'67
Yellow Springs	W. A. Anthony	1868	Fountain Dale	S. C. Walker	1868
Zanesfield	John F. Lukins	1854	Germantown	S. Ebert	1859
Zanesville	L. M. Dayton	1856	Germantown	Thos. Meehan and J. Meehan.	1862–'64
Zanesville	Adam Peters	1859			
Zanesville	J. G. F. Holston, M.D.	1853–'57	Germantown	Thomas Meehan	1859–'61
					1865–'68
OREGON.			Gettysburg	Prof. M. Jacobs	1849–'60
			Gettysburg	Rev. M. Jacobs and D. Eyster.	1861
Albany	S. M. W. Hindman	1865–'68			
Auburn	R. B. Ironside	1863–'65	Gettysburg	Rev. M. Jacobs and H. E. Jacobs.	1862–'65
Auburn	S. M. W. Hindman	1864–'65			
Corvallis	A. D. Barnard	1866–'68	Grampian Hills	Elisha Fenton	1864–'68
Fort Snyder	James A. Snyder	1858	Harrisburg	Dr. J. Heisely	1849–'68
Fort Thompson	W. H. Wagner	1857–'58	Harrisburg	W. O. Hickok	1857–'64
Oregon City	Geo. A. Atkinson	1851–'52	Harrisburg	K. A. Martin	1860–'61
Portland	Geo. H. Stebbins	1858–'59	Haverford	Dr. Paul Swift	1853–'63
Salem	Thos. H. Crawford	1861	Hollidaysburg	J. R. Lowrie	1853
Salem	P. L. Willis	1863–'65	Honesdale	M. H. Cobb	1852
			Horsham	Miss Anna Spencer	1864–'68
PENNSYLVANIA.			Huntingdon	Wm. Brewster, M. D	1859
			Ickesburg	Wm. E. Baker	1867–'68
Abington	Rodman Sisson	1864–'68	Indiana	David Peelor	1849–'51
Altoona	W. R. Boyers	1859–'60	Indiana	Wm. D. Hildebrand and David Peelor.	1858
Altoona	Thomas H. Savery	1863			
Andersville	R. Weiser	1854	Johnstown	David Peelor	1868
Beaver	Rev. R. T. Taylor	1867–'68	Kingsleys	Francis Schreiner	1852
Bedford	* Samuel Brown	1852–'58	Lancaster	F. A. Muhlenburg, jr	1849
Bedford	Rev. H. Heckerman	1859–'61	Lancaster	John Wise	1849–'51
Bellefonte	J. I. Burrell	1858–'59	Latrobe	Prof. Rudolph Muller.	1860–'62
Bendersville	Franklin W. Cook	1859	Latrobe	W. R. Boyers	1861
Bendersville	T. E. Cook & Sons	1859–'60	Lewisburg	Prof. C. S. James	1855–'60
Berwick	John Eggert	1856–'61			1865–'68
		1863–'65	Lima	Messrs. Edwards and Miller.	1849–'52
Bethlehem	L. R. Huebener	1849			
Bethlehem	Nathan C Tooker	1867	Lima	Joseph Edwards	1853
Bethlehem	Prof. A. M. Mayer	1867–'68	Lima	John H. Smedley	1859
Blairsville	W. R. Boyers	1861–'65	Linden	James Barrett	1858–'59
Blooming Grove	John Grathwohl	1865–'68	Manchester	Corydon Marks	1849–'52
Brookville	D. S. Deering	1854	Meadville	Prof. L. D. Williams	1849–'51
Byberry	John Comly	1852–'54	Meadville	T. H. Thickstun	1854–'58
		1857–'58	Media	Isaac N. Kerlin, M. D.	1860

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
PENN.—Continued.		
Moorhead	R. L. Walker	1863
Morrisville	Ebenezer Hance	1849–'64
Morrisville	Mahlon Moore	1859
Moss Grove	Francis Schreiner	1853–'57
Mount Joy	Mary E. Hoffer	1857–'58
Mount Joy	Dr. Jacob R. Hoffer	1860–'68
Murrysville	Thomas H. Stewart	1857–'59
Murrysville	F. L. Stewart	1867–'68
Nazareth	E. T. Kluge	1851
Nazareth	E. T. Kluge and E. Kummer.	1852
Nazareth	H. A. Brickenstein	1855–'57
Nazareth	J. C. Harvey	1859–'60
Nazareth	O. T. Huebner	1861
Nazareth	O. T. Huebner and L. E. Ricksecker.	1862
Nazareth	L. E. Ricksecker	1863–'66
New Castle	E. M. McConnell	1866–'68
Norristown	Rev. J. G. Ralston	1851–'63
Northeast	John T. Milliken	1867
North Whitehall	Edward Kohler	1856–'68
Oil City	James A. Weeks	1863–'64
Oxford	Henry Duffield, M. D.	1865
Paradise	Jacob Frantz	1854–'58
Parkerville	Fenelon Darlington	1859–'63 1865
Philadelphia	U. S. Navy-yard	1849
Philadelphia	Lt. Jos. Reed, U. S. N.	1849
Philadelphia	Dr. Paul Swift	1849–'52
Philadelphia	J. F. Coorlies	1849–'52
Philadelphia	Prof. J. A. Kirkpatrick.	1852–'60 1862–'68
Philadelphia	U. S. Naval Hospital	1857–'68
Philadelphia	J. C. Martindale, M. D.	1860–'61
Philadelphia	P. Friel	1863
Philadelphia	Homer Eachers	1864
Philadelphia	Penn'vania Hospital	1864–'65
Philadelphia	J. M. Ellis	1867
Pittsburg	Edward Fenderich	1849–'51
Pittsburg	Dr. H. Smyser	1849–'54
Pittsburg	W. W. Wilson	1852–'58
Pittsburg	Wm. Martin	1857
Pittsburg	John Hastings and Wm. Martin.	1855
Pittsburg	Wm. Martin and Dr. Alex. M. Speer.	1858
Pittsburg	Dr. Alex. M. Speer	1859–'61
Pittsburg	Prof. Rudolph Muller.	1863
Plymouth Meeting	Marcus D. Corson	1868
Pocopson	Fenelon Darlington	1853–'58 1866–'68
Pottsville	John Hughes	1854–'55
Pottsville	Dr. A. Heger	1855
Pottsville	Rev. B. R. Smyser	1857
Pottsville	D. Washburn	1858
Randolph	Orrin T. Hobbs	1851–'52 1854–'56
Reading	John Heyl Raser	1857–'63 1866–'68
Reading	Dr. J. B. Peale and Charles Hahn.	1858
Scranton	Dr. A. P. Meybert	1858
Sewickleyville	John I. Travelli	1859–'60
Sewickleyville	J. I. Travelli and G. H. Tracy.	1861
Sewickleyville	George H. Tracy	1862
Shamokin	P. Friel	1856–'63
Silver Spring	H. G. Bruckart	1863–'68
Somerset	Rev. David J. Eyler	1852
Somerset	Dr. F. Chorpenning	1856
Somerset	George Mowry	1857–'61
Stevensville	J. Russell Dutton	1866–'67
St. Mary's	Wm. A. Stokes	1849
Sugar Grove	Lorin Blodget	1849–'51
Sugar Grove	W. O. Blodgett	1852–'54
Summit Hill	M. Abbott	1852
Summitville	Thos. Seabrook	1852
Susquehanna Depot	H. H. Atwater	1863
Tarentum	John H. Baird	1856–'60
PENN.—Continued.		
Tioga	E. T. Bentley	1863–'68
Towanda	S. J. Coffin, W. H. Dean, i. H. Kingsbury.	1861
Troy Hill	Victor Scriba	1855–'56
Uniontown	Freeman Lewis	1849
Valley Forge	C. P. Jones	1849
Warrior's Mark	J. R. Lowrie	1854
Waynesboro'	Rev. D. J. Eyler	1853–'54
Wellsboro'	Henry W. Thorp	1849
Westchester	Samuel Alsop	1858–'59
Westchester	Prof. A. G. Clark and T. H. Aldrich.	1864–'65
Westchester	Dr. Geo. Martin	1868
Whitehall Station	Edward Kohler	1859–'60
Williamsport	H. C. Moyer	1864
Worthington	Samuel Scott	1859–'62
Youngsville	Dr. A. C. Blodget	1853–'54
RHODE ISLAND.		
East Greenwich	E. G. Arnold	1855–'56
Newport	Samuel Powel	1854
Newport	Wm. H. Crandall	1865–'68
North Scituate	Henry C. Sheldon	1853–'54
Portsmouth	Geo. Manchester	1854
Providence	Prof. A. Caswell	1849–'67
Providence	H. C. Sheldon	1860–'64
SOUTH CAROLINA.		
Aiken	H. W. Ravenel	1854–'56
Aiken	Rev. J. H. Cornish	1857–'61 1867–'68
Anderson	E. S. Earle	1868
Barrattsville	Dr. Jno. P. Barratt	1849–'51
Beaufort	Dr. M. M. Marsh and Mrs. Marsh.	1863–'65
Black Oak	Thos. P. Ravenel	1858–'61
Camden	J. A. Young, M. D.	1849–'51 1854–'57
Camden	T. Carpenter	1851–'54
Charleston	Prof. L. R. Gibbes	1851
Charleston	Dr. Jos. Johnson	1855–'57
Charleston	J. L. Dawson, M. D.	1857
Charleston	Jos. Johnson, M. D., and J. L. Dawson, M. D., and G. S. Pelzer, M. D.	1858–'61
Columbia	Col. W. Wallace	1851
Columbia	F. H. Harleston	1856
Columbia	Prof. J. B. White	1856
Columbia	Capt. C. C. Tew	1858
Columbia	E. H. Barton, M. D.	1859
Columbia	Sup't Arsenal Acad'y.	1859
Edisto Island	E. N. Fuller	1855–'57
Georgetown	Rev. Alex. Glennie	1859–'61
Gowdysville	Charles Petty	1868
Hilton Head	Maj. J. W. Abert, U. S. Eng., Capt. C. R. Suter.	1864
Hilton Head	Maj. C. R. Suter, U. S. Engineers.	1865
Mount Pleasant	E. N. Fuller, M. D.	1857
Orangeburg	Thos. A. Elliott	1849
Orangeburg	Joseph T. Zealy	1849
St. Johns	H. W. Ravenel	1849–'52
St. Johns	Thos. P. Ravenel	1859–'60
Waccaman	Rev. Alex. Glennie	1854–'58
Wilkinsville	Chas. Petty	1866–'67
TENNESSEE.		
Austin	S. K. Jennings, M. D.	1860–'61
Austin	P. B. Calhoun	1868
Chattanooga	Dr. G. H. Blaker	1864
Clarksville	Prof. W. M. Stewart	1851–'68
Dixon Springs	Thos. L. Sawyer	1852
Dover	B. F. Tavel	1849

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
TENN.—Continued.		
Elizabethton	Charles H. Lewis	1868
Fayetteville	Dr. W. W. McNulty	1849–'51
Franklin	Jos. M. Parker, M. D	1867
Friendship	Dr. Robert T. Carter	1854–'55
Greenville	S. S. & W S. Doak	1866–'68
Knoxville	O. W. Morris	1851–'52
Knoxville	Prof. Geo. Cooke	1853
Knoxville	Prof. Geo. Cooke and L. Griswold.	1854
Knoxville	T. L. Griswold	1855–'56
Knoxville	Stephen C. Dodge	1860
La Grange	J. R. Blake	1859–'60
Lebanon	Prof. A. P. Stewart	1851–'54
Lebanon	Prof. B. C. Jilson	1854
Lookout Mountain	Edward F. Williams	1866–'67
Lookout Mountain	Rev. C. F. P. Bancroft	1867–'68
Memphis	U. S. Navy Yard	1849, '53
Memphis	R. Harris	1851–'52
Memphis	* W. J. Tuck, M. D.	1857–'58
Memphis	Dr Daniel F. Wright	1857
Memphis	Drs. W J. Tuck and R. W. Mitchell.	1859
Memphis	R. W. Mitchell, M. D.	1860–'61
Memphis	Edward Goldsmith	1867–'68
Nashville	Prof. Jas. Hamilton	1849
Nashville	Wm. Rothrock	1849
Nashville	James Higgins	1854
Nashville	Fred. H. French	1867–'68
Pomona	J. W. Dodge & Son	1859–'61
Trenton	Prof. Hamilton	1854
University Place, Franklin county.	Chas. R. Barney	1859–'61
Walnut Grove	James B. Bean	1856–'57
Winchester	S. W. Houghton	1859–'60
TEXAS.		
Aransas	Frederick Kaler	1860
Austin	Dr. Sam'l K. Jennings	1852–'56
Austin	J. W. Glenn	1854
Austin	Dr. S. K. Jennings and J. Van Nostrand.	1857
Austin	Swante Palm	1858–'64
Austin	J. Van Nostrand	1858–'61 1867–'68
Bastrop	J. D Cunningham	1859
Bonham	Prof. Solomon Sias	1859–'60
Boston	G. Freese	1860–'61
Boundary Survey	John H. Clark	1859
Burkeville	Dr. N. P. West	1859–'61
Cedar Grove Pl'n	Hennell Stevens	1867–'68
Chappell Hill	W. H. Gantt	1866–'67
Columbus	Dr. W. G. De Graffenried.	1859
Cross Roads	F. S. Wade	1859–'60
Dallas	John M. Crockett	1859
Galveston	Drs. C. H. Wilkinson, H. A. McComly, and others.	1867
Geological Survey	Geo. G. Shumard	1859
Gilmer	J. M. Glasco	1859–'61 1867–'68
Goliad	John C. Brightman	1857–'58
Gonzales	Melvin H. Allis	1859–'61
Greenville	Dr. R. De Jernett	1859–'60
Helena	John C. Brightman	1856–'57
Houston	* Dr. A. M. Potter	1862–'65
Houston	Miss E. Baxter	1867–'68
Huntsville	H. Yoakum	1849–'51
Huntsville	J. H. Browne	1852
Huntsville	T. Gibbs	1858–'60
Kaufman	James T. Rayal	1859–'66
Kaufman	James Brown	1866
Jefferson	W. T. Epperson	1859
Larissa	F. L. Yoakum	1858–'60
Long Point	M. Rutherford	1867
New Braunfels	A. Forke and Otto Friedrich.	1857
New Braunfels	Otto Friedrich	1858–'60
TEXAS—Continued.		
New Wied	T. C. Ervendberg	1849–'54
New Wied	J. L. Forke	1855–'57
Pope's Expedition	James M. Reade	1855–'57
Port La Vaca	James Gardiner	1859
Roundtop	Bruno Shuman	1859–'61
San Patricio	J. O. Gaffoey	1859–'60
Sisterdale	Ernest Kapp	1859–'60
Springfield	T. A. Turner	1859
Tarrant	Dr. B. L. D'Spain and J. M. Ewing.	1859–'60
Texana	William Colman	1859
Turner's Point	James Rayal	1861
Union Hill	Dr. Wm. H. Gant	1857–'61
Waco	Edward Merrill, M. D.	1867–'68
Washington	B. H. Rucker	1856–'60
Webberville	Prof. C. W. Yellowby	1859–'61
Wheelock	F. Kellog	1859–'61
Woodboro	Dr. Jas. E. Moke	1859–'60
UTAH.		
Gt. Salt Lake City	H. E. Phelps	1857
Gt. Salt Lake City	H. E. Phelps and W. W. Phelps.	1858
Gt. Salt Lake City	W. W. Phelps	1859–'61 1863–'68
Harrisburg	James Lewis	1867–'68
Heberville	Harrison Pearce	1860–'61
Rockville	Andrew L. Siber	1866
St. George	Harrison Pearce	1862–'64
St. George	H. Pearce and G. A. Burgon.	1865–'66
St. Mary's	Thomas Bullock	1865
Vineland	Andrew L. Siber	1864
Wanship	Thomas Bullock	1866–'68
Washington	Harrison Pearce	1860
VERMONT.		
Barnet	B. F. Eaton, M. D	1866–'67
Bradford	L. W. Bliss	1856–'57
Brandon	* D. Buckland	1852–'64
Brandon	Harmon Buckland	1864–'67
Brattleboro'	Charles C. Frost	1849–'51
Brookfield	T. F. Pollard	1863
Burlington	Prof. Zadok Thompson.	1849–'54
Burlington	McK. Petty	1857–'64
Calais	James K. Toby	1861–'64
Castleton	D. Underwood	1852–'54
Charlotte	M. E. Wing	1868
Craftsbury	Chas. A. J. Marsh	1853–'54
Craftsbury	* James A. Paddock	1855–'67
East Bethel	Charles L. Paine	1865
East Montpelier	B. J. Wheeler	1855
Lunenburg	Hiram A. Cutting	1859–'68
Middlebury	Prof. W. H. Parker	1849–'52
Middlebury	Harmon A. Sheldon	1865–'68
Montpelier	D. P. Thompson	1849, '51
Montpelier	M. M. Marsh	1863
North Craftsbury	Rev. Edward P. Wild	1867–'68
Norwich	A. Jackman	1855–'59
Randolph	R. M. Manley	1849–'51
Randolph	Charles L. Paine	1866–'68
Rupert	Joseph Parker	1857–'63
Rutland	* S. O. Mead	1862–'64
Saxes' Mills	J. C. Baker	1855
Shelburne	George Bliss	1855–'57
Springfield	Rev. J. W. Chickering	1860–'63
St. Johnsbury	J. K. Colby and J. P. Fairbanks.	1853–'55
St. Johnsbury	Franklin Fairbanks	1857–'61
West Fairlee	L. W. Bliss	1858
Wilmington	Rev. John B. Perry	1866–'67
Woodstock	Charles Marsh	1857–'58
Woodstock	Lester A. Miller	1867
Woodstock	H. Doten and L. A. Miller.	1868

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations.
VIRGINIA.		
Anna	Rev. C. B. McKee	1858–'59
Alexandria	Benj. Hallowell	1849 1853–'58
Ashland	Samuel Couch	1851 1856–'57
Berryville	Miss E. Kownslar	1855–'57
Berryville	Dr. R. Kownslar	1858
Bridgeton	C. R. Moore	1868
Bridgewater	J. d. Hotchkiss	1852, '54
Buffalo	Prof. G. R. Rossiter	185[illegible]–'54
Buffalo	Samuel Couch	1855, '58
Buffalo	Wm. R. Boyers	1858–'59
Cape Charles	* Jas. G. Potts	1867–'68
Charleston	Jas. E. Kendall	1856–'57
Charlottesville	Chas. J. Meriwether	1849–'51
Charlottesville	J Ralls Abell	1859–'61
Christiansburg	Wm. C. Hagan	1851
Cobham	Chas. J. Meriwether	1852
Cobham Depot	Geo. C. Dickinson	1859–'61
Crichton's Store	R. F. Astrop	1852–'61
Diamond Grove	R. F. Astrop	1849–'51
Falmouth	Abraham Van Doren	1859–'61
Fredericksburg	Chas. H. Roby	1859–'61
Fredericksburg	B. R. Wellford	1849
Fork Union	Silas B. Jones	1859–'61
Garysville	T. S. Beckwith, M. D.	1856
Garysville	Julian C. Ruffin	1859
Gosport	United States Navy Yard.	1849
Hartwood	Abraham Van Doren	1858
Heathsville	J. C. Wills	1849
Hewlett's	J. F. Adams	1867
Holliday's Cove	B. D. Sanders	1858
Johnsontown	C. R. Moore	1868
Leesburg	N. F. D. Browne	1849
Leesburg	Samuel X. Jackson	1854
Lexington	Wm. K Park	1861
Lexington	W. H. Ruffner	1867–'68
Lloyd	Geo. W. Upshaw	1859
Longwood	Thos. J. Wickline	1857
Lynchburg	A. Nettleton	1854
Lynchburg	Chas. J. Meriwether	1866–'68
Madison	Dr. A. M. Grinnan	1851–'52
Meadow Dale	James Slaven	1857–'59
Middlesex	L. C. Breckenstein	1852
Montcalm	Chas. J. Meriwether	1854
Montrose	H. H. Fauntleroy	1856–'57
Montross	Edwd. E. Spence	1858–'59
Mossy Creek	Jed. Hotchkiss	1856–'58
Mount Solon	Jas. T. Clarke	1855–'56 1867–'68
Mustapha	James Fraser	1857–'58
New England	James Fraser	1859–'61
Norfolk	United States Naval Hospital.	1868
Portsmouth	N. B. Webster	1852–'60
Portsmouth	Naval Hospital	1860–'61
Powhatan Hill	Edward T. Tayloe	1849–'68
Prince Edward	Prof. Frs. J. Nuttaner	1849–'52
Richmond	David Turner	1849–'54
Richmond	Chas. J. Meriwether	1859–'61
Richmond	John Appleyard	1860
Rose Hill	Geo. W. Upshaw	1857–'58
Rougemont	Geo. C. Dickinson	1857–'58
Ruthven	Julian C. Ruffin	1856–'58
Salem	J. Carson Wells	1857–'58
Smithfield	John R. Purdie	1856–'61
Snowville	J. W. Stalnaker	1867–'68
Staunton	J. B Imboden	1849
Staunton	J. C. Covell	1868
Stribling Springs	Jed. Hotchkiss	1859
Surry	Benj. W. Jones	1867–'68
The Plains	John Pickett	1859–'60
Winchester	J. W. Marvin	1852–'61 1859–'61
Wytheville	W. D. Roedel	1861
Wytheville	Howard Shriver	1865–'66
Wytheville	Rev. Jas. A. Brown	1868

Name of station.	Name of observer.	Years of observations.
WASHINGTON TERRITORY.		
Fort Colville	Capt. Hague	1860–'61
Fort Steilacoom	David Walker, M. D.	1863–'64
Fort Vancouver	Dr Barnes	1859
Neeah Bay	James G. Swan	1862–'66
Neeah Bay	Alexander Sampson	1867
Port Townsend	S. S. Bulkley	1867–'68
WEST VIRGINIA.		
Ashland	Charles L. Roffe	1865–'68
Burning Springs	Robert H. Bliven	1867–'68
Capon Bridge	J. J. Offutt, M. D.	1857
Crackwhip	D. H. Ellis	1856–'57
Grafton	D. W. H. Sharp	1867–'68
Hampshire county	S. J. Stumps	1868
Harper's Ferry	L. J. Bell	1860
Huntersville	Wm. Skeen	1851–'56
Kanawha	David L. Ruffner	1856–'57
Kanawha	James E. Kendall	1858 1860–'61
Kanawha Salines	W. C. Reynolds	1858–'59
Lewisburg	Dr. Wm. N. Patton	1851–'52
Lewisburg	Dr. Thos. Patton	1853–'57
Lewisburg	Thos. Patton and J. W. Stalmaker.	1858
Lewisburg	J. W. Stalmaker	1859–'61
New Creek Station	Hendricks Clark	1856–'65
Point Pleasant	W. R. Boyers	1858
Romney	Marshall McDonald	1852
Romney	W. H. McDowell	1866–'68
Sistersville	Enoch D. Johnson	1857–'58
Wardensville	D. H. Ellis	1855 1859–'61
Wellsburg	B. D. Sanders	1859–'60
Weston	Benjamin Owen	1868
West Union	W C. Quincy	1855–'56
Wheeling	* Geo. P. Lockwood	1859–'60
Wirt	Josiah W. Hoff	1856–'58
WISCONSIN.		
Appleton	Prof. R. Z. Mason	1856–'61
Appleton	John Hicks	1867
Appleton	Dr. M. J. E. Hurlburt	1867
Appleton	Prof. J C. Foye	1867–'68
Ashland	Edwin Ellis	1862
Aztalan	James C. Brayton	1849–'52
Baraboo	Dr. B. F. Mills	1849–'52
Baraboo	M. C. Waite	1864–'68
Bay City	Edwin Ellis	1857–'58
Bayfield	Harvey J. Nourse	1858–'59
Bayfield	Andrew Tate	1867–'68
Bellefontaine	Thomas Gay	1851–'54
Beloit	Prof. S. P. Lathrop	1849–'54
Beloit	J. McQuigg and W. Porter.	1854
Beloit	Prof. Wm. Porter	1855–'60
Beloit	Prof. Henry S. Kelsey	1861–'62
Beloit	Henry D. Porter	1863–'67
Black River Falls	Emil Hauser	1859
Brighton	George Mathews	1862–'63
Burlington	D. Matthews	1859
Burlington	D. and G. Matthews	1860
Burlington	George Mathews	1861
Caldwell Prairie	S. Armstrong	1860–'61
Cascade Valley	Samuel R. Seibert	1856
Ceresco	Miss M. E. Baker	1854–'55
Dartford	M. H. Towers	1861–'62
Delafield	Prof. A. W. Clark	1859–'60
Delafield	Chas. W. Kelly	1861–'63
Delavan	Levens Eddy	1864–'67
Edgerton	Henry J. Shintz	1867–'68
Emerald Grove	Orrin Dinsmore	1849–'52
Embarras	J. Everett Bend	1864 1866–'68
Falls of St. Croix	M T. W. Chandler	1857
Falls of St. Croix	Wm. M. Blanding	1858
Galesville	Wm. Gale	1867–'68

List of Smithsonian meteorological stations and observers—Continued.

Name of station.	Name of observer.	Years of observations
WIS.—Continued.		
Geneva	Wm. H. Whiting	1863–'68
Green Bay	Col. D. Underwood	1859
Green Bay	Frederick Deckner	1864–'65
Green Lake	C. F. Pomeroy	1851–'52
Hartford	Judge Hopewell Cox	1859–'62
Hingham	John De Lyser	1867–'68
Hudson	G. F. Livingston	1854
Janesville	J. F. Willard	1853–'58
Janesville	Geo. J. Kellogg	1859
Janesville	Dr. Clark G. Pease	1860–'61
Janesville	Daniel Strunk	1862
Kenosha	Rev. John Gridley	1851–'52 1857–'63
Kilbourn City	James H. Bell	1860–'62
Lake Mills	Isaac Atwood	1859–'62
Lebanon	J. C. Hicks	1864
Lind	R. H. Struthers	1858
Madison	Prof. S. H. Carpenter	1853
Madison	S. H. Carpenter and J. W. Sterling.	1854
Madison	A. Schue, M. D.	1856–'58
Madison	Prof. J. W. Sterling	1856–'59 1863–'65
Madison	J. Jennings	1860
Madison	Prof. J. W. Sterling and S. P. Clarke.	1860
Madison	Prof. J. W. Sterling and W. Fellows.	1861–'62
Manitowoc	Jacob Lüps	1857–'68
Menasha	Col. D. Underwood	1857–'58
Milwaukee	I. A. Lapham	1849–'52 1854 1857–'68
Milwaukee	Carl Winkler, M. D.	1854–'67
Milwaukee	F. C. Pomeroy	1855–'59
Milwaukee	Prof. E. P. Larkin	1859–'61
Mosinee	J. S. Pashley	1859
Mount Morris	Wm. F. Horsford	1858
New Holstein	Ferdinand Hachez	1865
New Lisbon	John L. Dunegan	1867–'68
WIS.—Continued.		
New London	J. Everett Breed	1857–'58
Norway	John E. Himoe	1855–'57
Odanah	Edwin Ellis, M. D.	1863–'66
Otsego	L. H. Doyle	1859–'60
Pardeeville	S. Armstrong	1859–'60
Platteville	Dr. J. L. Pickard	1851–'59
Platteville	A. K. Johnson	1859–'60
Plymouth	G. Moeller	1865–'68
Prescott	Spencer L. Hillier	1857
Racine	Rev. Roswell Park	1856
Racine	W. J. Durham	1856–'58
Racine	Hiland W. Phelps	1860–'61
Ripon	Prof. W. H. Ward	1865–'66
Rocky Run	W. W. Curtis	1859–'68
Rural	R. H. Struthers	1860–'61
Southport	Rev. John Gridley	1849
Summit	Edward S. Spencer	1851–'54
Superior	Wm. H Newton and L. Washington.	1855
Superior	L. and R. Washington, and C. Loring, jr.	1856
Superior	Wm. Mann	1859–'63
Superior	G. R. Stuntz and E. H. Bly.	1859–'63
Waterford	S. Armstrong	1863
Watertown	William Ayres	1852
Waukesha	Prof. S. A. Bean	1855–'56 1858–'59
Waukesha	Prof. S. A. Bean and L. C. Slye, M. D.	1857
Waupacca	J. Everett Breed	1856, '65
Waupacca	H. C. Mead	1863–'68
Waupaca	C. D. Webster	1867
Wausau	W. A. Gordon, M. D.	1859–'60
Weyauwega	Melzar Parker	1860–'61
Weyauwega	William Woods	1861–'64
Weyauwega	John C. Hicks	1866
Weyauwega	* Dr. Jas. Matthews	1866
Whittlesey	Edwin Ellis, M. D.	1859–'60

Alphabetical list of meteorological observers of the Smithsonian Institution, up to the end of the year 1868.

Name.	State.	Name.	State.
Abbe, Cleveland	Michigan.	Astrop, R. F	Virginia.
Abbott. M	Pennsylvania.	Atkins, Rev. L. S	Ohio.
Abell, B. F	Ohio.	Atkinson, George A	Oregon.
Abell, J. Ralls	Virginia.	Atkinson, William A	Iowa.
Abert, Major J. W	South Carolina.	Atwater, H. H	Pennsylvania.
Abert, Thayer	Florida.	Atwood, Isaac	Wisconsin.
Acadia College	Nova Scotia.	Aubier, Rev J. M	New York.
Adams, E. L	Massachusetts.	Austin, W. W	Indiana.
Adams, Prof. E. W	North Carolina.	Avery, Charles A	New York.
Adams, I R	New York.	Ayres, W	Wisconsin.
Adams, J F	Virginia.	Ayres, Dr. W. O	California.
Adams, J. F	Georgia.	*Babcock, A. J	Illinois.
Adams, Jno. W	Maine.	Babcock, Dr. B. F	Minnesota.
Adams, W. H	Illinois.	Babcock, E	Illinois.
Adams, W P	New York.	Babcock, E	Iowa.
Agnew, J. C	Missouri.	Bachelder, F. L	Florida.
Agricultural College	Kansas.	Bachelder, J	Massachusetts.
Alba, E. M	New York.	Bacon, D. G	Kansas.
Alcott, W. P	Massachusetts.	Bacon, E. E	Illinois.
Aldrich, T. H	Pennsylvania.	Bacon, Frank M	Michigan.
Aldrich, Verry	Illinois.	Bacon, William	Massachusetts.
Alexander, Arch	New Jersey.	Baer, Miss H. M	Maryland.
Alexander, Captain R. E	Bermuda.	Baer, Prof. W	Maryland.
Alexander, J. M	New York.	Bailey, James B	Florida.
Alison, H. L	Alabama.	Bailey, S. S	Missouri.
Allen, Edwin	New Jersey.	Bailey, Thomas	Massachusetts.
Allen, Prof. E. A. H	New York.	Baird, John H	Pennsylvania.
Allen, Frederick	Ohio.	Baird, Prof. S. F	Pennsylvania.
Allen, George D	Florida.	Baker, Frank	Illinois.
Allen, Prof. G. N	Ohio.	Baker, J C	Vt. & Canada.
Allen, James, jr	Michigan.	Baker, Miss M. E	Wisconsin.
Allen, J. P	Nebraska.	Baker, N. T	Illinois.
Allen, W. D	New York.	Baker, William E	Pennsylvania.
Allin, Lucius C	Massachusetts.	Baldwin, Dr A. S	Florida.
Allis, Melvin H	Texas.	Baldwin, Elmer	Illinois.
Allison, Jesse	Illinois.	Ball, Miss Ida E	Iowa.
Allison, Thomas A	North Carolina.	Ball, Dr. J. E	Iowa.
Alsop, Samuel	Pennsylvania.	Ball, James H	New York.
Alter, Dr. D	Pennsylvania.	Ballou, N. E	Illinois.
Alvord, D S	Ohio.	Bambach, Dr. G	Ohio.
Ammen, J	Ohio.	Bancroft, Rev. C. F. P	Tennessee.
Anderson, C. F	Minnesota.	Bandelier, Adolphus F., jr.	Illinois
Anderson, H. H	Indiana.	Bannister, H. M	Alaska Ter.
Anderson, Dr. James	Georgia.	Barbage, Joshua C	Kentucky.
Anderson, W. H	Indiana.	Barber, Prof. G. M	Ohio.
Andrews, G P	Michigan.	Barker, Thomas M	Alabama.
Andrews, Prof. J. W	Ohio.	Barlow, Dennis	Arkansas.
Andrews, Seth L	Michigan.	Barnard, Alonzo	Minnesota.
Andrus, W. C	Florida.	Barnard, A. D	Oregon.
Angell, B. D	Indiana.	Barnes, C	Indiana.
Anthonioz, B. F	Louisiana.	Barnes, Dr.	Washington Ter
Anthony, Newton	Ohio.	Barney, Charles R	Tennessee.
Appleyard, John	Virginia.	Barratt, Rev J. P	South Carolina.
Arden, Thos. B	New York.	Barrett, James	Pennsylvania.
Armstrong, M. K	Dakota Ter.	Barrows, A. C	Ohio.
Armstrong, S	Wisconsin.	Barrows, G. B	Maine.
Arnold, E G	Rhode Island.	Barrows, N	Massachusetts.
Arnold, James B	Bermudas.	Barrows, Storrs	New York.
Arnold, Mrs. J. T	Georgia.	Bartlett, E. B	New York.
Astron. Observatory, Williams College	Massachusetts.	Bartlett, Isaac	Indiana.
		Bartlett, Joshua	Maine.

*Deceased.

Alphabetical list of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
*Barton, Dr. E. H.	S. Car. and La.	Bly, E. H	Wisconsin.
Bassett, G. R	Illinois.	Board of Trade	Nova Scotia.
Batchelder, F. L.	Florida.	Boardman, G. A.	Florida.
Baxter, Miss E	Texas.	Boerner, C. G	Indiana.
Beal, Dexter	Iowa.	Boettner, Gustave A	Illinois.
Beal, W. W	Iowa.	Bogert, W. S.	Florida.
Beaman, Carlisle D	Iowa.	Bond, Isaac	Maryland.
Bean, Dr James B	Fla. and Tenn.	*Bond, W. C	Massachusetts.
Bean, Prof. S. A	Wisconsin.	Bosworth Prof. R. S	Ohio.
Beans, Thomas J	New Jersey.	Boucher, W. K.	California.
Beardsley, L. A	New York.	Bowen, Miss Anna M. J	Kansas.
Beatty, O	Kentucky.	Bowen, J. S	Kansas.
Beauchamp. W. M.	New York.	Bowen, Wm. F	Ohio.
Beckwith, E. W	Mississippi.	Bowles, Dr. S. B	Missouri.
Beckwith, Dr. T. F	Virginia.	Bowlsby, G. W	Michigan.
Beckwith. W	Kansas.	Bowman. E. H	Illinois.
Beecher, Michael	Ohio.	Bowman, John	New York.
Behmer, Frederick	Missouri.	Boyd, S. T	Ohio.
Belcher, W. C.	California.	Boyers, W. R	Pennsylvania.
Belfield H. H	Iowa.	Boyle, C. R	Iowa.
Bell, Miss E. M. A	Illinois.	Brackett, G. E	Maine.
Bell. Jacob E	Maryland.	Brayton, Jas. C	Wisconsin.
Bell, James H	Wisconsin.	Brayton, Milton	Sombrero Isl'd.
Bell, J. J	Maine.	Breckenstein, L. C	Virginia.
Bell, Louis	New Hampshire.	Breed, J. Everett	N. Y. and Wis.
Bell. L. J	Virginia.	Breed, M. A	Illinois.
Bell, Lewis J	Maryland.	Brendel, Dr. E	Illinois.
Bell, Hon. S. N	New Hampshire.	Brendel, Dr. F	Illinois.
Benagh, George	Alabama.	Brewer, Rev. Fisk P	North Carolina.
Benner, J. F	Ohio.	Brewer, F. A	Massachusetts.
Bennett, Henry	Ohio.	Brewster, Alfred	New Hampshire.
Bennett, Sarah E	Ohio.	Brewster, Wm., M. D	Pennsylvania.
Benton, F. A	Ohio.	Brickenstein, Rev. H. H	Illinois.
Berendt, G	Mexico.	Brinkerhoff, G. M	Illinois.
Berger, M. L	Massachusetts.	Briggs, E. L	Iowa.
Berky, W. H	Kansas.	Brightman, J. C	Texas.
Berthoud, E. L	Ky. Kas., &Col.	Brooks, Rev. Jabez	Minnesota.
Betts, Charles	Michigan.	Brooks, Hon. J	Massachusetts.
Bickford, Calvin	Maine.	Brooks, Wm	New Jersey.
Bidwell, Dr. E. C	Iowa and Ohio.	Brookes, Samuel	Illinois
Binkerd, J S	Ohio.	Brown, Branch	New Hampshire.
Birney, James G	Michigan.	Brown, B. G	New Hampshire
Bixby. A. H	N.H., Ky., & Ind.	Brown, E. E	Maine.
Bixby, J. H	Massachusetts.	Brown, G. W	Kansas.
Blackman, W. J. R	Kansas.	Brown, H. H	Kansas.
Blackwell, Thomas	Canada.	Brown, James	Texas.
Blackwell, W. H	Arkansas.	Brown, Rev. J. J.	New York.
Blake, H	Indiana.	Brown, J. W	Illinois.
Blake, J R	Tennessee.	Brown, N. W	Massachusetts.
*Blaker, Dr. G. H	Tenn. and Mich.	Brown, Prof. P. P	Illinois.
Blakeslee, Rev. S. V	California.	Brown, P. P	Ind. Ter.
Blanchard. Orestes A	Illinois.	*Brown, Samuel	Pennsylvania.
Blanding, William M	Wisconsin.	Brown, W. B. G	New Hampshire
Blewitt, Rev. W	Georgia.	Browne, J. H	Texas.
Bliss, George	Vermont.	Browne. N. F. D	Virginia.
Bliss, L W	Vermont.	Brown, O. H	Kansas.
Bliven, Robert H	West Virginia.	Buckart, H. G	Pennsylvania.
Blodgett. Dr. A. C	Pennsylvania.	Brugger, S	Pennsylvania.
Blodget, Lorin	Pennsylvania.	Bryant, A. F	Iowa.
Blodget, W O	Pennsylvania.	Bryant, C. H	Illinois.
Bloodgood, S. De Witt	New York.	Buck, Rufus	Maine.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
*Buckland, D	Vermont.	Chapman, J. P	New York.
Buckner, Rev. H. F	Arkansas.	Chapman, N. A	Ohio.
Bulkeley, S. S	Wash. Ter.	Chappelsmith, J	Indiana.
Bullard, Ransom	Michigan.	Chase, Arthur	New Hampshire.
Buller, E. A	Maine.	Chase, Dr. Charles	New Hampshire.
Bullock, J. T	Indiana.	Chase, Cornelius	New York.
Bullock, Thomas	Utah.	Chase, C. Thornton	New York.
Burgon, G. A	Utah.	Chase, Milton	Michigan.
Burras, O	Ohio.	Chase, T	Ohio.
Burrell, J. I	Pennsylvania.	Cheney, W	Minnesota.
Burris, Dr. Robert	Arkansas.	Chickering, J. W	New York.
Burroughs, R	Indiana.	Chickering, Rev. J. W	Vermont.
Burt, Henry M	Nebraska.	Child, Dr. A. L	Nebraska.
Burton, John	Delaware.	Child, Miss J. E	Nebraska.
Bush, Rev. Alva	Iowa.	Childs, E. W	Ohio.
Bussing, D. S	New York.	Chorpenning, Dr. F	Pennsylvania.
Bussing, J. W	New York.	Christian, John	Missouri.
Butterfield, W. W	Indiana.	Clark, Prof. A. G	Pennsylvania.
Butterfield, Mrs	Indiana.	Clark, Prof. A. W	Maryl'd & Wis.
Byers, Dr. Robert	Missouri.	Clark, Dr. D	Michigan.
Byers, S. M	Minnesota.	Clark, Sereno	New York.
Byers, William N	Nebraska.	Clark, Hendricks	West Virginia.
Byram, E. N	New York.	Clark, Thomas	Minnesota.
Byrne, Arthur M	Illinois.	Clark, W. P	Ohio.
Calder, J. G	Bermudas.	Clarke, John	Ohio.
Caldwell, John H	Massachusetts.	Clarke, J. T	Virginia.
Caldwell, John T	Missouri.	Clarke, Lawrence, jr	Hud. Bay Ter.
Caldwell, R. H	Kentucky.	Clarke, Mrs. Lawrence	Hud. Bay Ter.
Calhoun, P. B	Tennessee.	Clarkson, Rev. D	Kansas.
Calloway, J. W	North Carolina.	Cleland, Rev. T. H	Kent'y & Miss.
Camp, Benjamin F	Georgia.	Clement, John, jr	New Jersey.
Camp, E. P	Kansas.	Clough, J. B	Minnesota.
Campbell, J	Missouri.	Cockburn, S	Honduras.
Campbell, Dr. W. M	Michigan.	Cobb, M. H	Pennsylvania.
Canfield, Dr. C. A	California.	Cobb, M. H	Connecticut.
Cantril, J. E	Illinois.	Cobbs, Rev. R. A	Alabama.
Canudas, Ant	Guatemala.	Cobleigh, Prof. N. E	Illinois.
Capen, E	Illinois.	Coffin, Prof. J. H	Pennsylvania.
Carey, Daniel	Illinois.	Coffin, Matthew	Michigan.
Carll, Albert G	New York.	Coffin, Selden J	Pennsylvania.
*Carothers, A. G	Bahamas.	Coffin, Prof. William	Illinois.
Carpenter, B	Iowa.	Cotrau, L. R	Maryland.
Carpenter, Prof. S. H	Wisconsin.	Colburn, Ed	Ohio.
Carpenter, S. O	New York.	Colby, Alfred	New Hampshire.
Carpenter, T	South Carolina.	Colby, E. P	New Hampshire.
Carter, J. H	Louisiana.	Colby, J. K	Vermont.
Carter, Rev. J. P	Maryland.	Cole, Barker	New Jersey.
Carter, Prof. P	Ohio.	Cole, E. C	New Jersey.
Carter, Dr. Robert T	Tennessee.	Coleman, J. A	Alabama.
Carter, Thomas	North Carolina.	Collier, Alfred	Massachusetts.
Carver, Rev. E. W	Minnesota.	Collier, D. C	Colorado.
Carver, Dr. R. T	Tennessee.	Collier, Prof. George H	Illinois.
Case, Dr. C. D	Kentucky.	Collin, Prof. Alonzo	Iowa.
Case, Jarvis	Connecticut.	Collins, Rev. Samuel	Indiana.
Caswell, Prof. A	Rhode Island.	Collins, Colonel W. O	Idaho.
Caswell, Rev. R. C	Newfoundland.	Colman, William	Texas.
Cavileer, Chas	Minnesota.	Comings, G. P	Missouri.
Chadbourne, Prof. P. A	Mass. & Conn.	Comly, John	Pennsylvania.
Chamberlain, J	Iowa.	Conant, Marshall	Massachusetts.
Chandler, Charles Q	Missouri.	Conkling, Thomas J	Missouri.
Chandler, Dr. George	Massachusetts.	Connolly, H	Hud. Bay Ter.
Chandler, M. T. W	Wisconsin.	Cook, E. B	New York.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Cook, Ephr. R	New Jersey.	Darlington, F	Pennsylvania.
Cook, F. W	Pennsylvania.	Dascomb, Professor	Ohio.
Cook, Prof. George H	New Jersey.	Davidson, H. M	Ohio.
Cook, Thomas E., & Sons	Pennsylvania.	Davidson, W	Ohio.
Cook, W. H	Pennsylvania.	Davies, James F	Arkansas.
Cooke, Prof. George	Tennessee.	Davis, Charles	Pennsylvania.
Cooke, R. L	New Jersey.	*Davis, Rev. Dr. Emerson	Massachusetts.
Cooper Female Seminary	Ohio.	Davis, George L. C	Mississippi.
Cooper, Dr. George F	Georgia.	Davis, R. J	Virginia.
Coorlies, J. F	Pennsylvania.	Davis, W. E	Ohio.
*Corey, Henry M	Florida.	Dawson, John L	South Carolina.
Cornette, Rev. A	Alabama.	Dawson, W	Indiana.
Cornish, Rev. J. H	South Carolina.	Day, Theodore	Pennsylvania.
Corse, John M	Iowa.	Day, William	New York.
Corson, Rev. Marcus H	Pennsylvania.	Dayton, E. A	New York.
Cotting, J. M	Georgia.	Dayton, Lewis M	Ohio.
Cotton, Dr. D. B	Ohio.	Dayton, James H	Indiana
Couch, E. D	New Jersey.	Deacon, John C	New Jersey.
Couch, Samuel	Virginia.	Dean, W. H	Pennsylvania.
Coues, Dr. E	Arizona.	Dearing, D. S	Pennsylvania.
Coulter, B. F	Arkansas.	Deckner, Frederick, & Son.	Georgia & Wis.
Covell, J. C	Virginia.	Deem, D	Indiana.
Coventry, W. B	Indiana.	Deering, D. S	Iowa & Penn'a.
Covert, A. B	New York.	De Graffenreid, Dr. W. G.	Texas.
Cowing, Philo	New York.	De Jernett, Dr. R	Texas.
Cox, Judge Hopewell	Wisconsin.	De Lyser, J	Wisconsin.
Craigie, Dr. W	Canada West.	*Delaney, E. M. J	Newfoundland.
Crandall, William H	Rhode Island.	*Delaney, John, jr	Newfoundland.
Crandon, F	Illinois.	Denig, E. T	Nebraska.
Crane, George W	Ohio.	Denison, H. L	Kansas.
Crane, Heber	Michigan.	*Denning, W. H	New York.
Craven, Rev. B	North Carolina.	Dennis, W. C	Florida.
Craven, Thomas J	Delaware.	Desellen, J. N	Ohio.
Crawford, R	Delaware.	*Dewey, Prof. C	New York.
Crawford, W. A	Delaware.	Dewhurst, Rev. E	Me., Mass., & Ct.
Crawford, T. H	Oregon.	De Wyl, N	Missouri.
Cribbs, J. R	Mississippi.	D'Spain, Dr. B. L	Texas.
Crisp, John F	Indiana.	Dickinson, George C	Virginia.
Crisson, J. C	Bahamas.	Dickinson, James P	Iowa.
Crocker, Allen	Kansas.	Dickson, Walter	Hud. Bay Ter.
Crockett, John M	Texas.	Dill, John B	New York.
Croft, Charles	California.	Dille, Israel	Ohio.
Crookham, George L	Ohio.	Dinsmore, H. L	New York.
Crosby, J. B	Michigan.	Dinsmore, O	Wisconsin.
Crozier, Dr. E. S	Indiana.	Doak, S. S	Tennessee.
Crowther, Benjamin	Mexico.	Doak, W. S	Tennessee.
Cumming, S. J	Alabama.	Dodd, Prof. C. M	Indiana.
Cunningham, Miss Ardelia	Ohio.	Dodder, E. L	Pennsylvania.
Cunningham, G. A	Massachusetts.	Dodge, J. W., & Son	Tennessee.
Cunningham, J. D	Texas.	Dodge, Stephen C	Tennessee.
Currier, Alfred O	Michigan.	Dodson, B. D	Missouri.
Curtis, W. W	Wisconsin.	Dole, J. G	Ohio.
Cutler, Prof. E	Connecticut.	Dorat, Dr. Charles	San Salvador.
Cutting, Ephr	California.	Dorsey, S. S	Ohio.
Cutting, Hiram A	Vermont.	Dorweiler, P	Iowa.
Dall, W. H	Alaska Territ'y.	Doten, H	Vermont.
Dalrymple, A. P	Maryland.	Doughty, William H	Georgia.
Dalton, O. D	Missouri.	Doyle, Joseph B	Ohio.
Dana, William D	Maine.	Doyle, L. H	Wisconsin.
Darby, Prof. John	Georgia & Ala.	Draper, Dr. Joseph	Massachusetts.
Darling, L. A	Massachusetts.		

*Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Drew, Dr F. P	Kansas.	Farnsworth, P. J	Iowa.
Drummond, Rev. J. H	Kansas.	Fauntleroy, H H	Virginia.
Drysdale, Robert H.	North Carolina.	Featherston, G W	Arkansas.
Dubois, H. G., jr	Connecticut.	Fellows, H. B	New York.
Dudley, T	Illinois.	Fellows, W	Wisconsin.
Duffield, Dr. E	Missouri.	Felt, C. W., and others	Massachusetts.
Duffield, Rev. Dr. George	Michigan.	Felt, John	New York.
Duffield, Dr. H	Pennsylvania.	Female College, Arkadelphia	Arkansas.
Duncan, Rev. Alexander	Illinois.	Fenderick, E	Pennsylvania.
Dungan, John L	Wisconsin.	Fendler, Aug	Massachusetts.
Dunkum, Mrs. E. S.	California.	Fendler, Aug	Missouri.
Dunkum, W. L	California.	Ferguson, G F	Florida.
Dunwoody, W. P.	Iowa.	Ferriss, E. J	Ohio.
Durham, W J	Wisconsin.	Finfrock, J. H	Idaho.
Dutton, J. Russell	Pennsylvania.	Finley, A. J	Iowa.
Eachers, Homer	Pennsylvania.	Finley, H S	Iowa.
Earle, E. S	South Carolina.	Finley, P. F	Arkansas.
Earle, J. W	New York.	Finley, R. W	Missouri.
Earle, Silas	California.	Fischer, Dr. James C	Ohio.
Easter, Prof. J. D	Georgia.	Fish, Edmund	Kansas.
Eaton, Dr. B. F	Vermont.	* Fish, Lucien	Kansas.
Ebert, S	Pennsylvania.	Fisher, Dr. J. C	Ohio.
Eddy, Levens	Wisconsin.	Fisher, Dr. Galen, M	Florida.
Edgerly, L. G	Illinois.	Fiske, W. M. L	New York.
Edwards, Daniel	New York.	Fitch, Dr. Joseph	Illinois.
Edwards & Miller	Pennsylvania.	Fitzgerald, Rev. F	North Carolina
Edwards, Joseph	Pennsylvania.	Fleming, John	New Jersey.
Edwards, Rev. Dr. Tryon	Connecticut.	Flett, Andrew	Hud. Bay Ter.
Eggert, John	Pennsylvania.	Flint, Prof. W	New York.
Eldridge, Rev. W. V	Illinois.	Flippin, W. B	Arkansas.
Elletson, Job	New York.	Florer, Thomas W	Mississippi.
Ellis, D. H	Massachusetts.	Foote, Elisha	New York.
Ellis, D. H	Virginia.	Folsom, C. A	Mississippi.
Ellis, J. M	Pennsylvania.	Force, N. P	Missouri.
Ellis, Dr. Edwin	Mich. & Wis.	Forey, J. C	Iowa.
Ellis, Dr. W. T	Colorado & Kas.	Forke, A	Texas.
Elliott, Jonathan	St. Domingo.	Forke, J. L	Texas.
Elliott, Prof. J. Boyd	Mississippi.	Foster, J. H	Michigan.
Elliott, J. C	Ohio.	Foster, Robert W	Louisiana.
Elliott, T. A	South Carolina.	Foster, W. L	Alabama.
Ellsworth, J	Illinois	Foye, Prof. J. C	Wisconsin.
Ellsworth, Lewis	Illinois.	Frantz, Jacob	Pennsylvania.
Ellsworth, M. S	Illinois.	Fraser, James	Ohio.
Elstun, W. J	Indiana.	Fraser, James	Virginia.
Engelbrecht, Lud	Ohio.	Fraser, James B	Ohio.
Engelmann, Dr. George	Missouri.	Freeman, F. N	New Hampshire.
Epperson, W. T	Texas.	Freeman, H. C	Illinois.
Ervendberg, Dr. L. C	Mexico.	Freese, G	Texas.
Ervendberg, T. C.	Texas.	French, Fred. H	Tennessee.
Evans. John	Nebraska.	French, I. S	New Hampshire.
Eveleth, S	Maine.	French, J. B	New Hampshire.
Eveleth, Samuel A	Maine.	French, J. R	New York.
Everett, Franklin	Michigan.	Frey, Samuel C	Ohio.
Ewing, J. M	Texas.	Friedrich, Otto	Texas.
Eyler, Rev. D. J	Pennsylvania.	Friel, P	Pennsylvania.
Eyster, D	Pennsylvania.	Fries, G. W	New York.
Fairall, H. H	Iowa.	Fritts, J. S	New Jersey.
Fairchild, Prof. J. H	Ohio.	Frombes, Prof. Oliver S	California.
Fairchild, John P	New York.	Frost, Prof. A	New Jersey.
Fairbanks, F	Vermont.	Frost, C. C	Vermont.
Fairbanks, J. P	Vermont.	Frost, Colonel E. C	New York.
Fallon, John	Massachusetts.		

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Fry, Lieutenant Joseph	Florida.	Grant, C. W	Illinois.
Fuller, Dr. E. N	South Carolina.	Grant, Miss Ellen	Illinois.
Fuller, R. M	New York.	Grant, J	Illinois.
Fuller, W. G	Ohio.	Grant, Dr. W. T	Georgia.
Gaffney, J. O	Texas.	Grape, George S	Maryland.
Gaines, Rev. A. G	Maine.	Grathwohl, J	Pennsylvania.
Gale, W	Wisconsin.	Grave, Mary A	Minnesota.
Gamble, J. W	Ohio.	Green, A. R	Mississippi.
Gantt, Dr. W. H	Texas.	Greene, Prof. Dascom	New York.
Gardiner, James	Texas.	Gregory, S. O	New York.
Gardiner, J. H	New York.	Gridley, Rev. J	Wisconsin.
Gardiner, R. H	Maine.	Griest, John	Indiana.
* Gardiner, Hon. R. H	Maine.	Griest, Miss M	Indiana.
Garland, J. G	Maine	Griffing, Henry	Illinois.
Garland, Samuel G	Bahamas.	Griffith, R. H	Michigan.
Garrison, O. E	Minnesota.	Grinnell, J	Kentucky.
Garvin, Dr. P. C	Florida.	Griswold, L	Tennessee.
Gary, Jacob S	New Jersey.	Griswold, T. L	Tennessee.
Gay, Thomas	Wisconsin.	Groesbeck, Mrs. E. W	Kansas.
Gay, V. P	Illinois.	Groff, T. Louis	Illinois.
Gibbes, Prof. L. R	South Carolina.	Groneweg, L	Ohio.
Gibbon, Lardner	Florida.	Guest, W. E	New York.
Gibbons, H	California.	Gunn, Donald	Hud. Bay Ter.
Gibbons, J. S	New York.	Guptill, G. W	Maine.
Gibbs, T	Texas.	Haas, Henry	New York.
Gibson, H	Nebraska.	Habersham, S. E	Georgia.
Gibson, R. T	Georgia.	Hachez, Ferd	Wisconsin.
Giddings, Rev. George B	Illinois.	Hagan, W. E	Virginia.
Gidley, I. M	Iowa.	Hagensick, J. M	Iowa.
Gifford, B. R	Louisiana.	Hague, Captain	Washington Ter.
Gifford, R. R	Massachusetts.	Hahn, Charles	Pennsylvania.
Giles, F. W	Kansas.	Haines, John	Indiana.
Gill, Joseph H	Illinois.	Haines, William	Georgia.
Gillingham, W	Maryland.	Hall, Dr. A	Canada.
Gilliss, Charles J	Massachusetts.	Hall, Joel	Illinois.
Gilman, Stephen	Maine.	Hall, Joseph H	New Hampshire
Gilman, W. H	Kansas.	Hall, S. W	Maine.
Gilman, W. S., jr	New York.	Hallowell, Benjamin	Virginia.
Gilmore, M	Ohio.	Hamaker, Marion F	Missouri.
Gilmour, A. H. J	Canada.	Hamilton, Prof. J	Tennessee.
Glasco, J. M	Texas.	Hamilton, Captain W	Bahamas.
Glenn, J. M	Texas.	Hamilton, Rev. W	Nebraska.
Glennie, Rev. Alex	South Carolina.	Hamilton, W. H	North Carolina.
Glover, Eli S	Georgia.	Hammitt, J. W	Ohio.
Goff, Mrs. M. A	Michigan.	Hampton, W. C	Ohio.
Gold, T. S	Connecticut.	Hanan, B. P	Missouri.
Goldsmith, E	Tennessee.	Hance, Ebenezer	Pennsylvania.
Goodman, W. R	Maryland.	Hanna, G. B	Massachusetts.
Goodnow, I. T	Kansas.	Hannaford, E	Ohio.
Gordon, Robert	California.	Hanscom, R. F	New Hampshire.
Gordon, Dr. W. A	Wisconsin.	Hanshew, Henry E	Maryland.
Gorton, J. S	New York.	Harding, Colonel Horace	Alabama.
Goss, B. F	Kansas.	Hardy, H. F	Arkansas.
Goss, George C	Iowa.	Hardy, Dr. J. F. E	North Carolina.
Goss, W. K	Iowa.	Harkness, W	New York.
Gould, Lewis A	California.	Harper, G. W	Ohio.
Gould, M	Maine.	Harper, Prof. L	New Jersey.
Graham, J	New York.	Harper, Prof. L	Mississippi.
Graham, Paul	Arkansas.	Harris, A. J	Alabama.
Grant, Benjamin	Pennsylvania.	Harris, Dr. J. O	Illinois.
Grant, Charles	Georgia.	Harris, R	Tennessee.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Harrison, B. F	Connecticut.	Hollenbeck, F	Ohio.
Hart, J. H	New York.	Holley, Benj. F	Alabama.
Hartt, C. F	Nova Scotia.	Hollingworth, G. W	Kansas.
Harvey, J. C	Pennsylvania.	Hollister, Dr. J	Michigan.
Haskin, W L	New York.	Holmes, D. J	Massachusetts.
Hastings, J	Pennsylvania.	Holmes, E. S	New York.
Haswell, Rev. J. R	New York.	Holmes, Dr. E. S	Michigan.
Hatch, A. L	Mississippi.	Holmes, J. C	Michigan.
Hatch, Dr. F. W	California.	Holmes, Thomas	Indiana.
Hatch, H	Mississippi.	Holston, Dr. J. G. F	Ohio.
Hatch, J	New Hampshire.	Holt, Rev. Jos. W	Minnesota.
Hatfield, Jos C	Ohio.	Holt, William	Illinois.
Hauser, Emil	Illinois & Wis.	Hoover, W	Ohio.
Haven, S. F	Massachusetts.	Hopkins, Prof. A	Massachusetts.
Hawks, Dr. J. M	Florida.	Hopkins, Rev. Robert	Minnesota.
Hayes, Dr. W. W	California.	Hopkins, Prof. W. F	Maryland.
Hayne, J. B	Bahamas.	Horn, Miss Clotilde	Kansas.
Haywood, Prof. J	Ohio.	Horn, Dr. H. B	Kansas.
Heaston, D. J	Missouri.	Horner, W. H	Missouri.
Heckerman, Rev. H	Pennsylvania.	Horr, Dr. Asa	Iowa.
*Hedges, Urban D	Delaware.	Horr, Ed. W	Iowa.
Heger, Dr. A	Pennsylvania.	Horsford, William F	Wisconsin.
Heimstreet, J. W	N. Y. and Minn.	Hosmer, A	New York.
Heisely, Dr. J	Pennsylvania.	Hotchkiss, Jed	Virginia.
Helm, Thos. B	Indiana.	Hough, Dr. F. B	New York.
Henderson, W	Alabama.	Houghton, G S	Pennsylvania.
Herrick, F. C	Kentucky.	Houghton, S. W	Tennessee.
Herrick J. D	Ohio.	House, J. C	New York.
Hester, Lieut. J. W	Florida.	House, J. Caroll	New York.
Heubner, O. T	Pennsylvania.	Howard, J. S	Arkansas.
Heyser, W., jr	Pennsylvania.	Howe, Edwin	California.
Hibbard, A. A	N. Y. and Minn.	Howell, R	New York.
Hickok, W. O	Pennsylvania.	Hoyt, Peter L	New Hampshire.
Hicks, John	Wisconsin.	Hudson, Dr. A. T	Iowa.
Hicks, J. C	Wisconsin.	Huebener, L. R	Pennsylvania.
Hicks, Dr. W. R	North Carolina.	Huestis, Prof. A. C	Indiana.
Hieto, J. A	Mexico.	Huffaker, S. S	Missouri.
Higgins, Prof. D. F	Nova Scotia.	Hughes, Jno	Pennsylvania.
Higgins, James	Tennessee.	Hull, A. B	Connecticut.
*Hildreth S. P	Ohio.	Hunt, Ashley D	Alabama.
Hill, F. G	Ohio.	Hunt, Rev. D	Connecticut.
Hill, G. D	Dakota.	Hunt, George M	New York.
Hill, L. J	Nebraska.	Hunt, Dr. S. B	New York.
Hillier, Rev. Spencer L	N.Y., Ohio, Wis., and Minn.	Huntingdon, George C	Ohio.
		Hurlburt, Dr M. J. E	Wisconsin.
Himoe, John E	Wisconsin.	Hurlin, Rev. W	New Hampshire.
Himoe, Dr. S. O	Kansas.	Hurtt, F. W	Ohio.
Hindman, S. M. N	Oregon.	Huse, Frederick J	Illinois.
Hiscox, G D	Illinois.	Huston, T. A	Alabama.
Hoadley, C H	Connecticut.	Hyde, G. A	Mass. and Ohio.
Hobart, Ed. F	Iowa.	Hyde, Mrs. G. A	Ohio.
Hobbs, Chas. M	Indiana.	Hyde, Stephen	New York.
Hobbs, Miss M A	Indiana.	Hyde, Rev. T. C P	New York.
Hobbs, Orin T	Pennsylvania.	Imboden, J. B	Virginia
Hobbs, William H	Indiana.	Ingalls, S. Marshall	New York.
Hoff, Dr. Alex. H	Alaska Ter.	Ingalsbee, Grenville M	New York.
Hoff, J. W	Virginia.	Ingersoll, J. D	New York.
Hoffer, Dr. J. R	Pennsylvania.	Ingraham & Hyland	Kansas.
Hoffer, Mary E	Pennsylvania.	Ingram, Dr. J	Ohio and N. J.
Holcomb, A	Massachusetts.	Ironside, R B	Oregon.
Hollenbeck, D. K	Ohio.	Irvine, Professor S. G	Ohio.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Ives, Edward R	Florida.	*Kennicott, R	Alaska & Hud. Bay Territory.
Ives, William	New York.	Kent, Benjamin	Massachusetts.
Jackman, A	Vermont.	Kerlin, Dr. I. N	Pennsylvania.
Jackson, Dr. A. W	Louisiana.	Kerr, Prof. W. C	North Carolina.
Jackson, John	Pennsylvania.	Kersey, Dr. V	Indiana.
Jackson, Samuel X	Virginia.	Kibbe, T. R	California.
Jacobs, H. E	Pennsylvania.	Kilgore, W	Minnesota.
Jacobs, Prof. M	Pennsylvania.	Kilpatrick, Dr. A. R	Louisiana.
Jaeger, H. W	Ohio.	King, Mrs. Adelia C	Ohio.
James, Miss Anna	Illinois.	King's College	Nova Scotia.
James, Prof. C S	Pennsylvania.	Kingsbury, J. H	Pennsylvania.
*James, Dr. John	Illinois.	Kirby, D. J	Massachusetts.
Janes, C. C	Ohio.	Kirkpatrick, Prof. J. A	Pennsylvania.
Jaque, A	Ohio.	Kirtland, Dr. J. P	Ohio.
Jenkins, John F	New York.	Kizer, W. B	Missouri.
Jenkins, J. L	Illinois.	Kluge, E. T	Pennsylvania.
Jennings, J	Wisconsin.	*Kluge, Dr. J. P	New Granada.
Jennings, Dr. Samuel K	Ala., Texas, and Tenn.	Knauer, J	Indiana.
Jilson, B. C	Tennessee.	Knox, James C	New Hampshire.
Johns, Dr. Montgomery	Maryland.	Knoud, Rev. James	Missouri.
Johnson, A. K	Wisconsin.	Kohler, Edward	Pennsylvania.
Johnson, Enoch D	Virginia & Ohio.	Kohleski, Theo	Montana.
Johnson, E. W	New York.	Koning, Rev. P. W	Missouri.
Johnson, Joseph	South Carolina.	Kownslar, Miss E	Virginia.
Johnson, Norton	Illinois.	Kownslar, Dr. R	Virginia.
Johnson, R. C	Nevada.	Kridelbaugh, S. H	Iowa.
Johnson, Rev. Samuel	New York.	Kron, F. J	North Carolina.
Johnson, Thomas H	Ohio.	Kummer, E	Pennsylvania.
Johnson, Warren	Maine.	Kunster, H	Illinois.
Johnson, Dr. W. M	North Carolina.	Laighton, Thomas B	New Hampshire.
Johnson, W. W	Montana.	Landon, Anna S	New York.
Johnston, Prof. John	Connecticut.	Landon, Stephen	New York.
Johnston, William M	Mississippi.	Lane, Prof. C. W	Georgia.
Jones, Benjamin W	Virginia.	Lane, John	Michigan.
Jones, C. P	Pennsylvania.	Lane, Moses	New York.
Jones, Prof. Gardner	Indiana.	Langdon, Laurens A	New York.
Jones, Josiah	Maryland.	Langee, Dr. Ignatius	Iowa.
Jones, Silas B	Virginia.	Langguth, J. G., jr	Illinois.
Jones, W. Martin	Canada.	Langworthy, A. Darwin	Illinois.
Jorgenson, C. N	Iowa.	Lapham, Darius	Ohio.
Jourdan, Prof. C. H	Maryland.	Lapham, I. A	Wisconsin.
Joy, Prof. Charles A	New York.	Larkin, Prof. E. P	Wisconsin.
Julien, Alexis A	Antilles.	Larrabee, W. H	Indiana.
Kaler, Frederick	Texas.	Larsh, T. J	Ohio.
Kapp, Ernst	Texas.	Laselle, C B	Indiana.
Kaucher, William	Missouri.	Laszlo, Charles	Mexico.
Kedzie, Prof. R. C	Michigan.	Lathrop, Prof. S. P	Wisconsin.
Keenan, T. J R	Mississippi.	Latimer, George	Porto Rico.
Keep, Rev. W. W	Florida.	Lattimore, Prof. S. A	New York.
Kellett, Thomas A	Minnesota.	Lawson, G. W	Dakota.
Kelley, O. H	Minnesota.	Lea, John	Ohio.
Kellogg, F	Texas.	Lear, O. H. P	Missouri.
Kellogg, G. J	Wisconsin.	Learned, Dwight W	Connecticut.
Kellum, A. O	Wisconsin.	Leavenworth, D. C	Connecticut.
Kelly, Charles W	Minnesota.	Lee, Charles A	New York.
Kelsey, Prof. H. S	Wisconsin.	*Lefferts, John	New York.
Kelsey, Kathalo	New York.	Leffman, L	New York.
Kemper, G. W. H	Indiana.	Lefroy, Capt. J. H	Canada.
Kendall, James	Virginia.	*Lehman, Dr. H. M	Montana.
Kendall, John F	New York.	Leonard, Rev. L. W	New Hampshire.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Leonard, W. P	Iowa.	McKee, Rev. C. B	Dist. Col. & Va.
Levings, Chas	Illinois.	McKenzie, J. M	Iowa & Neb.
Lewis, Charles H	Tennessee.	McLain, W. D	Colorado.
Lewis, James	Utah.	McMasters, Professor S. Y	Ill's and Ken.
Lewis, James	New York.	McMillan, S. B	Ohio.
Lingow, B. G	Missouri.	McMullen, J. F	Minnesota.
Linus, M	New York.	McMore, P. A	New York.
Lippincott, James S	New Jersey.	McNelty, Dr. W. W	Tennessee.
Lippincott, Joseph W	New Jersey.	McNett, E. L	Pennsylvania.
Little, Frank	Michigan.	McQuigg, J	Wisconsin.
Little, J. Thomas	Illinois.	McWilliams, Dr. Alex	Maryland.
Livezay, G. W	Ohio.	Macfarlane, R	Hud. Bay Ter.
Livings, B. C	Minnesota.	Macgregor, C. J	Canada.
Livingston, G. F	Wisconsin.	Mack, A. W	Massachusetts.
Livingston, Prof. Wm	Illinois.	Mack, E. T	New Jersey.
Lobdell, Mrs. M. J	New York.	Mack, Rev. E. T	New York.
Locke, Samuel	Minnesota.	Mack, Robert C	New Hampshire
Lockhart, James	Hud. Bay Ter.	Mackenzie, J	Hud. Bay Ter.
*Lockwood, G. P	Virginia.	Mackie, M	New York.
Logan, Dr. T. M	California.	Magee, I	New York.
Loines, Dr. J. P	New York.	Magnetic Observatory	Canada.
Lord, W. G	Maine.	Maguire, Professor J. F	Maryland.
Loring, C	Wisconsin.	Malcolm, W. S	New York.
Loughridge, Dr. J. H	Indiana.	Malden, J. J	Michigan.
Love, Mrs. James	Iowa.	Mallinckrodt, C	Missouri.
Love, Louisa P	Iowa.	Manchester, Geo	Rhode Island.
Lowndes, B. O	Maryland.	Mankard, Mrs. M. J	Louisiana.
Lowrie, J. R	Pennsylvania.	Manley, R. M	Vermont.
Lüps, Jacob	Wisconsin.	Mann, Wm	Wisconsin.
Lukins, John F	Ohio.	Mapes, H. H	Michigan.
Lull, James S	Mississippi.	Marcy, Professor O	Illinois.
Lumpkin, W. M	Missouri.	Marks, Corydon	Pennsylvania.
Lumsden, Rev. William	Ohio.	Marlow, Colonel W. B	Jamaica.
*Lunemann, John H	Missouri & Ky.	Marsh, Chas	Vermont.
Lupton, N. T	Alabama.	Marsh, C. A. J	Vermont.
Luther, S. M	Ohio.	Marsh, M. M	Vermont.
Luttrell, James	Colorado.	Marsh, Mrs. M. M	Ohio.
Lynde, C. J	Wisconsin.	Marsh, O. J	Illinois.
Lyons, Curtis J	Massachusetts.	Marsh, Roswell	Ohio.
McAfee, J. R	Georgia.	Marshall, Gregory	Iowa.
McBeth, Miss Sue	Arkansas.	Martin, Dr. Alex	Indiana.
McCarty, H. D	Kansas & Ohio.	Martin, Dr. Geo	Pennsylvania.
*McCary, Robert	Mississippi.	Martin, Dr. G. Alex	Arkansas.
McCary, William	Mississippi.	Martin, K. A	Pennsylvania.
McClung, C. L	Ohio.	Martin, R. A	Delaware.
McComly, Dr. H. A	Texas.	Martin, Dr. Samuel D	Kentucky.
McConnell, E. M	Pennsylvania,	Martin, W	Pennsylvania.
McConnell, Townsend	Iowa.	Martindale, Dr. Jos. C	Pennsylvania.
McCormick, J. O	Maryland.	Martindale, Isaac C	Pennsylvania.
McCormick, William A	Kansas.	Marvin, J. W	Virginia.
McCoy, A. R	Pennsylvania.	Mason, Edgar E	Nebraska.
McCoy, Dr. F	Iowa & Indiana.	Mason, Professor R. Z	Wisconsin.
McCoy, Miss Lizzie	Iowa & Indiana.	Mather, Professor W. W	Ohio.
McCready, Daniel	Iowa.	Mathews, D	Wisconsin.
McDonald, M	Virginia.	Mathews, Geo	Wisconsin.
McDowell, Rev. A	North Carolina.	*Matthews, Dr. J	Wisconsin.
McDowell, W. H	West Virginia.	Mathews, Jos. McD	Ky. and Ohio.
McDowell, W. W	North Carolina.	Mathis, H. C	Kentucky.
McElrath, J. J	Arkansas.	Matthews, H. W	New York.
McElroy, Barnet	Pennsylvania.	*Matthews, Prof. M. M	New York.
McGee, J	Massachusetts.	Mattison, Andrew	Kentucky.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Mauld Dr. D. W	Delaware.	Moore, Jos	Indiana.
Mauncey, Rev S W	Minnesota.	Moore, Mahlon	Pennsylvania.
Mauran, Dr. P. B	Florida.	Moore, Dr. S. P	Louisiana.
Maurice, C. F	New York.	Moore, Dr. W	Missouri.
Maxey, W F	Missouri	Morehouse, A. W	New York.
Mayer, Professor Alfred M.	Md. & Pa.	Morelle, Professor D	North Carolina.
*Mayhew, Royal	Indiana.	Morris, Miss E	New York.
*Meacham H. G	Illinois.	Morris, Professor O. W	New York.
Meacham, S	Illinois.	Morris, O. W	Tennessee.
*Mead, Allen	Iowa.	*Morrison, W. H	Illinois.
Mead, Chauncey	Iowa.	Morse, Geo. M	Massachusetts.
Mead, H. C	Wisconsin.	Morse, J. P	New York.
Mead, Dr. S. B	Illinois.	Moses, J	Nicaragua.
*Mead, Stephen O	Vt. and N. H.	Moss, G. B	Illinois.
*Mead, Dr. Thompson	Illinois.	Moulton, J. P	Maine.
Meehan, J	Pennsylvania.	Moulton, M. M	Iowa.
Meehan, Thos	Pennsylvania.	Moultrie, J. L	Alabama.
Meeker, Ralph E	Illinois.	Mowry, Geo	Pennsylvania.
Menfield, Geo. C	Indiana.	Moyer, H C	Pennsylvania.
Meriwether, C	Virginia.	Muhlenberg, F. A., jr	Pennsylvania.
Meriwether, C. J	Virginia.	Muir, Wm	Missouri.
Meriwether, R. T	Alabama.	Muller, Professor R	Pennsylvania.
Merriam, A. M	Massachusetts.	Mulligan, A	New York.
Merriam, A. M	Colorado.	Mulvey, Oliver	Indiana.
Merriam, C. C	New York.	Munfield, Geo. C	Indiana.
Merriam, G. F	Kansas.	Munger, L. F	New York.
Merriam, Sidney A	Massachusetts.	Murch, E M	Kentucky.
Merrick. Thos. B	New Jersey.	Murdoch, G	New Brunswick.
Merrill, Dr. E	La. and Texas.	Mussey, R. D	Massachusetts.
Merrill, Rev. S. H	Maine.	Myers, J. H	Missouri.
Merritt, John C	New York.	Nash, Rev. J. A	Iowa.
Merwin, Mrs. E. H	Illinois.	Nason, Rev. Elias	N. H. and Mass.
Messman, Dr. J	Iowa.	Naturaliste Canadien	Canada.
Metcalf, H	New York.	Naval Hospital	California.
Metcalf, Dr. John G	Massachusetts.	Naval Hospital	New York.
Meybert, Dr. A. P	Pennsylvania.	Naval Hospital	Massachusetts.
Miles, Thos. H	Kentucky.	Naval Hospital	Pennsylvania.
Military Post	Newfoundland.	Naval Station	New York.
Millard, A. J	Iowa.	Navy Yard	Florida.
Millard, Joseph D	Michigan.	Navy Yard	Pennsylvania.
Miller, C. H	Nebraska.	Navy Yard	Virginia.
Miller, Rev. J	Kentucky.	Navy Yard	Tennessee.
Miller, John H	Kansas.	Neely, E. B	Missouri.
Miller, L. A	Vermont.	Nelson, H M	Massachusetts.
Milliken, John T	Pennsylvania.	Nelson, Professor J. P	Maryland.
Mills, Dr. B. F	Wisconsin.	Nelson, R. J	Nova Scotia.
Mills, John H	North Carolina.	Nelson, S. A	Massachusetts.
Minick, J. B	Michigan.	Nettleton, A	Virginia.
Mitchell, Dr. R. W	Tennessee.	Newcomb, Guilford S	Massachusetts.
Mitchell, Dr. S. F	Michigan.	Newcomb, J. B	Illinois.
Mitchell, Hon. W	Massachusetts.	Newkirk, R. M	Indiana.
Moeller, G	Wisconsin.	Newton, Rev. Alfred	Ohio.
Moffatt. Professor A. G	Indian Territory.	Newton, John	Florida.
Moke, Dr. Jas. E	Texas.	Newton, W. H	Wisconsin.
Moore, Professor A	Mississippi.	Nichols, C. L	Maine.
Moore, Dr. Alex. P	Arkansas.	Nicholson, Rev. J. J	Alabama.
Moore, Asa P	Maine.	Niell, Thos	Ohio.
Moore, Mrs. Belle	Missouri.	Noll, Arthur B	New Jersey.
Moore, C. R	Virginia.	Normal School	Massachusetts.
Moore, David	Mississippi.	North, Dr. S. B	Alabama.
Moore, Dr. G. F	North Carolina.	Norton, J. H	New York.
Moore, J. A	North Carolina.	Norton, Prof. W. A	Delaware.

*Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Norvell, F	Dakota Territ'y.	Pearson, John	Florida.
Nourse, H. J	Wisconsin.	Peck, Dr. John E	Florida.
Nutraner, Prof. Frs. J	Virginia.	Peck, Dr. W. R	Ohio.
Oakfield C. F	Kansas.	Peelor, David	Pennsylvania.
Oakley, Thomas	Mississippi.	Peet, Abraham S	Massachusetts.
Observatory Harvard College	Massachusetts.	Pelzee. George S	South Carolina.
O'Donoghue, John	Illinois.	Pendleton, Dr. E. M	Georgia.
Odell, Dr. B. F	Minn. and Iowa.	Pendleton, P. C	Georgia.
Odell, Fletcher	New Hampshire.	Percival, Dr. Charles F	Alabama.
Offutt, Dr. J. J	Virginia.	Perkins, Capt. A. D	Michigan.
Oficiana Central de Estadistica	Costa Rica.	Perkins, Dr. H. C	Massachusetts.
Olds, Warren	Illinois	Pernot, Claudius	New York.
Oliver, John	Michigan.	Perrault, Ed	Michigan.
Ormsby, G. S	Ohio.	Perry, Rev. J. B	Mass. and Vt.
Orton, James	Mass.	Perry, W	New Jersey.
Osborne, Dr. T. C	Alabama.	Peters, Adam	Ohio.
Osgood, H. H	Maine.	Peters, H	Indiana.
Owen, Benjamin	West Virginia.	Peters, Thos. M	Alabama.
Owen, Dr. D. D	Indiana.	Pettingill, Waldo	Maine.
Owsley, J. B	Ohio.	Pettingill, W	Ohio.
Packard, Levi S	New York.	Petty, Chas	South Carolina.
*Paddock, James A	Vermont.	Petty, McK	Vermont.
Paine, Charles L	Vermont.	Phelps, H. E	Utah.
Paine, Charles S	Vermont.	Phelps, Highland W	Wisconsin.
Paine, Dr. H. M	New York.	Phelps, Rev. Joshua	Iowa.
Palm, Swante	Texas.	Phelps, R. H	Connecticut.
Palmer, Miss Jerusha R	New Jersey.	Phelps, W. W	Utah.
Pardee, Eugene	Ohio.	Phillips, H	Canada.
Pardee, H. C	Nebraska.	Phillips, Prof. Jas., D. D	North Carolina.
Park, William K	Virginia.	Phillips, J. H	Ohio.
Park, Rev. Roswell	Wisconsin.	Phillips, R. C	Ohio.
Parker, J. B	Michigan.	Pickard, Dr. J. L	Wisconsin.
Parker, J. D	Maine.	Pickett, John	Virginia.
Parker, John D	Illinois.	Pierce, Warren	Ohio.
Parker, Joseph	Vermont.	Pillsbury, M. A	Ohio.
Parker, Dr. Joseph M	Tennessee.	Pillsbury, Mrs. M. A	Ohio.
Parker, Melzar	Wisconsin.	Pitcher, Dr. Zeno	Michigan.
Parker, Nathan H	Iowa.	Pitman, Charles H	New Hampshire
Parker, Prof. W. H	Vermont.	Pitman, E	Maine.
Parkinson, D. F	California.	Pitman, M	Maine.
Parmelee, Ezra	New York.	Plumb, Dr. Ovid	Connecticut.
Parry, William	New Jersey.	Plummer, Dr. John T	Indiana.
Parsons, B. W	Massachusetts.	Poe, James H	Ohio.
Parsons, L. H	New Jersey.	*Pollard, T. F	Vermont.
Partrick, J. M	New York.	Pollock, Rev. J. E	Missouri.
Parvin, P. G	Iowa.	Pomeroy, F. C	Wisconsin.
Parvin, Prof. Theo. S	Iowa.	Pool, Isaac A	Illinois.
Pashley, J. S	Wisconsin.	Poole, H	Nova Scotia.
Paterson, Rev. Dr. A. B	Minnesota.	Porter, E. D	Delaware.
Patrick, Dr. John J	Illinois.	Porter, Mrs. E. D	Delaware.
Pattison, H. A	Michigan.	Porter, Henry D	Wisconsin.
Patton, Thomas	Virginia.	Porter, Prof. W	Wisconsin.
Patton, Dr. Wm. N	Virginia.	*Posey, Dr. John F	Georgia.
Paxton, J. W	Michigan.	Post Surgeon	Kansas and Cal.
Payne, Dr. J. W	Alabama.	Potter, Dr. A. M	Texas.
Peabody, Prof. S. H	Vermont.	*Potter, C. D	New York.
Peale, Dr J. B	Pennsylvania.	Potter, G. W	New York.
Pearce, Harrison	Utah.	Potts, Jean G	Virginia.
Pearce, James A., jr	Maryland.	Powel, Samuel	Rhode Island.
		Pratt, Prof. D. J	New York.
		Pratt, George B	Iowa.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Pratt, Dr. J. F	Maine.	Robinson, Rev. E. S	Mississippi.
Prentiss, Dr. H. C	Massachusetts.	Roby, Charles H	Virginia.
Prescott, Dr. W	New Hampshire.	Rockwell, Miss Charlotte	Connecticut.
Preston, Rev. N. O	Kansas.	Rockwell, John A	Georgia.
Prince, Charles	Maine.	Rodman, Samuel	Massachusetts.
Prince, G	Maine.	Roe, J. H	Illinois.
Purdie, John R	Virginia.	Roe, Rev. Sanford W	Con. and N. Y.
Purdot, E	Honduras.	Roedel, W. D	Virginia.
Purmort, N	New Hampshire.	Roffe, C. L	West Virginia.
Quincy, W. C	Virginia.	Rogers, A. P	Ohio.
Race, James A	Missouri.	Rogers, Francis M	New York.
Raffensperger, E. B	Ohio.	Rogers, J. S	Illinois.
Rain, John G	Nebraska.	Rogers, O. P	Illinois.
Ralston, Rev. J. G	Pennsylvania.	Roos, Charles	Minnesota.
Rambo, E. B	Indiana.	Root, Dr. Martin N	Mass. and N.H.
Randall, R. B	California.	Root, Professor O	New York.
Rankin, Colin	H. B. T. & Canada.	Ross, B. R	H. B. Territory.
		Rosseau, M. C	Idaho.
Rankin, D. M	Ohio.	Rossiter, Professor G. R	Virginia.
Rankin, James	Connecticut.	Rothrock, William	Tennessee.
Ranlett, E. L	Louisiana.	Ray, G. P	Missouri.
Raser, John Heyl	Pennsylvania.	Royal Engineers	Bermudas.
Ravenel, H. W	South Carolina.	Royal Engineers	Nova Scotia.
Ravenel, Thomas P	South Carolina.	Royal Gazette	Bermudas.
Ray, Dr. John D	Kentucky.	Rucker, B. H	Texas.
Ray, L. G	Kentucky.	Ruffin, David L	Virginia.
Rayal, James T	Texas.	Ruffin, Julian C	Virginia.
Raymond, George	Massachusetts.	Ruggles, Homer	Missouri.
Raymond, W. A	Michigan.	Russell, Cyrus H	New York.
Read, D. E	Neb. and Iowa.	Russell, O. F	Arkansas.
Reade, J. M	Tex. & N. Mex.	Rutherford, M	Texas.
Reasure, Dr. F. M	Michigan.	Ryerson, Dr. Thomas	New Jersey.
Redding, Thomas B	Indiana.	Salisbury, Elias O	New York.
Reed, Edwin C	New York.	Samms, Dr. C. C	Ohio.
Reed, Isaiah	Iowa.	Sampson, Alexander	W. Territory.
Reed, Lt. Jos	Pennsylvania.	Sanders, B. O	Virginia.
Reid, Jas. M	Georgia.	Sanford, S	Ohio.
Reid, Dr. Robert K	California.	Sanford, Dr. S. N	Ohio.
Reid, Peter	New York.	Sanger, Dr. W. W	New York.
Reynolds, Henry	Maine.	Sargent, John S	Massachusetts.
Reynolds, J	Arkansas.	Sartorius, Dr. Charles	Mexico.
Reynolds, Lauriston	Maine.	Sartwell, Dr. H. P	New York.
Reynolds, Orrin A	Massachusetts.	Saurman, John W	Pennsylvania.
Reynolds, R. M	Alabama.	Savage, Dr. G. S	Kentucky.
Reynolds, W	Iowa.	Savery, Thomas H	Pennsylvania.
Reynolds, W. C	Virginia.	Saville, J. J	Iowa.
Rhees, Dr. Morgan J	New Jersey.	Sawkins, James G	Jamaica.
Rhoades, Dr. John	Ohio.	Sawyer, George B	N. Hampshire.
Rhodes, W. H. T	Texas.	Sawyer, H. E	N. Hampshire.
Riblet, J. H	Illinois.	Sawyer, Thomas L	Tennessee.
Rice, Frank H	Massachusetts.	Scandlin, Rev. Wm. G	Massachusotts.
Rice, Henry	Massachusetts.	Scarritt, Rev. N	Missouri.
Richards, Thomas	H. B. Ter'y.	Schauber, H. A	New York, Ohio, and Illinois.
Ricksecker, L. E	Pennsylvania.		
Riddell, Prof. W. P	Louisiana.	Scheeper, E. H. A	Iowa.
Riggs, A. L	Minnesota.	Schenck, Dr. W. L	Ohio.
Riggs, Rev. S. R	Minnesota.	Schetterly, Dr. H. R	Michigan.
Riker, Walter H	New York.	Schlegel, Albert	Massachusetts.
Riotte, Hon. C. N	Costa Rica.	Schley, W	Georgia.
Ritchie, James	Massachusetts.	Schmidt, Dr. E. R	New Jersey.
Riter, F. G	Dakota.	Scholefield N	Connecticut.
Robbins, Dr. James	Massachusetts.	Schriever, Francis	Pennsylvania.
Roberts, D. H	Indiana.	Schue, Dr. A	Wisconsin.
Robinson, Almon	Maine.	Scott, H. B	Florida.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Scott, James	Kansas.	Smith, C. B	Nebraska.
Scott, Samuel	Pennsylvania.	Smith, Dr. C. C	Michigan.
Scovill, H. W	Illinois.	Smith, C. E	Illinois.
Scriba, Victor	Pennsylvania.	Smith, Dr. Carl H	Ohio.
Seabrook, Thomas	Pennsylvania.	Smith, Eli	Maryland.
Seavey, C. C	Georgia.	Smith, Dr. E. A	Massachusetts.
Seibert, Samuel R	Wisconsin.	Smith, E. A., and daughters	New York.
Selby, Henry	Michigan.	Smith, E. L	Massachusetts.
Seltz, Charles	Nebraska.	Smith, Rev. George N	Michigan.
Senior class, Mount Auburn Female Institute	Ohio.	Smith, Dr. George O	Illinois.
		Smith, Haden Patrick	New York.
Sergeant, John T	New Jersey.	Smith, Hamilton, jr	Indiana.
Seymour, E	Wisconsin.	Smith, Henry K	Illinois.
Seymour, Dr. E. W	Kansas.	Smith, H. L	Minnesota.
Shackelford, Prof. J	Alabama.	Smith, Harmon M	Michigan.
Shaffer, J. M	Iowa.	Smith, Howard D	Maine.
Shane, J. D	Kentucky.	Smith, Isaac H	Illinois.
Sharp, Dr. W. H	West Virginia.	Smith, Dr. J. Bryant	North Carolina.
Shaw, Francis	Massachusetts.	Smith, J. C	Ohio.
Shaw, Jos	Ohio.	Smith, J. Edwards	Mississippi.
Shaw, M	Kansas.	Smith, John M	Missouri.
Sheerer, H. M	New York.	Smith, J. Metcalf	New York.
Sheldon, Daniel	Iowa.	Smith, Dr. J. W	New York.
Sheldon, D. S	Iowa.	Smith, Rev. L. M. S	Michigan.
Sheldon, H. A	Vermont.	Smith, M. D	California.
Sheldon, H. C	Rhode Island.	Smith, Mrs. M. D	California.
Shephard, J. A	Mississippi.	Smith, Dr. N. D	Arkansas.
Shepherd, Smiley	Illinois.	Smith, Rufus	New Hampshire
Sheppard, Benjamin	New Jersey.	Smith, Sydney	Iowa.
Sheppard, Clarkson	New Jersey.	Smith, Rev. S. U	Alabama.
Sheppard, Rev. J. A	N. C. and Ala.	Smith, Rev. W	Pennsylvania.
Sheppard, Miss R. C	New Jersey.	Smurr, Dr. T. A	Ohio.
Sherman, Rev. D. H	Illinois.	Smyser, Dr. B. R	Pennsylvania.
Shields, J. H	Alabama.	Smyser, Dr. H	Pennsylvania.
Shields, Rev. R	Ohio.	Snell, Prof. E. S	Massachusetts.
Shintz, H. J	Wisconsin.	Snow, Prof. F. H	Kansas.
Shoemaker, J. G	Kansas.	Snyder, James A	Oregon.
Shortwell, D. F	Minnesota.	Soule, Prof. W	New York.
Shotwell, Samuel L	Illinois.	Soule, W. L. G	Kansas.
Shreve, Charles R	Ohio.	Southworth, N. C	Michigan.
Shriver, Howard	Va. and N. J.	Spaulding, Dr. Abiram	Illinois.
Shuman, Bruno	Texas.	Spaulding, S. C	Illinois.
Shumard, G. G	Texas.	Spates, Samuel	Minnesota.
Sias, Professor Solomon	Tex. and N. Y.	Speer, Dr. Alex. M	Pennsylvania.
Siber, Andr. L	Utah.	Spencer, Miss Anna	Pennsylvania.
Sibley, P. B	Missouri.	Spencer, Edward E	Virginia.
Simpson, B. F	New Jersey.	Spencer, Rev. D. B	Minnesota.
Simpson, F. T	Georgia.	Spencer, E. S	Wisconsin.
Sisson, Rodman	Pennsylvania.	Spencer, W. C	Illinois.
Skeen, W	Virginia.	Spera, W. H	Pennsylvania.
Slade, Frederick J	New York.	Sperry, M	Ohio.
Slaven, J. B	California.	Spooner, E	Ohio.
Slaven, James	Virginia.	Spooner, Dr. S	New York.
Sloane, Prof. J. R. W	Ohio.	Spratt, Dr. W. W	Indiana & Ohio
Slye, L. C	Wisconsin.	Springer, Rev. Fr	Arkansas.
Smallwood, Dr. Charles	Canada.	Squier, H	Michigan.
Small, F. A	Maine.	Stagg, T. G	Maryland.
Smedley, John H	Pennsylvania.	Stalnaker, J. W	Virginia.
Smith, A. C	Minnesota.	Stanford, Colonel J. R	Georgia.
Smith, A. M	Bahamas.	Stanton, Fred. J	Colorado.
*Smith, Prof. A. W	Connecticut.	Stayman, Dr. J	Kansas.
Smith, Prof. B. Wilson	Iowa.	Stebbins, George H	Oregon.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Stebbins, Richard	Iowa.	Taylor, Dr. M. K	Michigan.
Steed, F	Iowa.	Taylor, Rev. R. T	Pennsylvania.
Steele, Hon. Aug	Florida.	Teele, Rev. A. K	La. and Mass.
Steele, George E	Michigan.	Tenbrock, J. W	Indiana.
Steiner, Dr. Lewis F	Maryland.	Terry, Charles C	Massachusetts.
Stephens, Prof. A. M	Minnesota.	Tew, Captain C. C	South Carolina.
Stephens, J. A	Missouri.	Thatcher, A. E	New York.
Stephenson, Rev. James	Maryland.	Thickstun, T. F	Minnesota.
Sterling, J. W	Wisconsin.	Thickstun, T. F	Pennsylvania.
Stern, Jacob T	Iowa.	Thomas, Mrs. W. S	Illinois.
Sternbergh, W. H	New Granada.	Thompson, A. H	Illinois.
Stevens, Hennell	Texas.	Thompson, Rev. D	Ohio.
Stevens, Dr. J. L	Maine.	Thompson, D. P	Vermont.
Stevens, Linus	New Hampshire.	Thompson, Rev. E	Ohio.
Stevens, R. P	Pennsylvania.	Thompson, E. P	Illinois.
Stewart, Prof. A. P	Tennessee.	Thompson, George W	New Jersey.
Stewart, F. L	Pennsylvania.	Thompson, H	Louisiana.
Stewart, Thomas H	Pennsylvania.	Thompson, Prof. H. A	Ohio.
Stewart, W. M	Tennessee.	Thompson, Mrs. Phœbe	Vermont.
Stockwell. George A	Michigan.	Thompson, R. O	Nebraska.
Stokes, H. A	New Jersey.	Thompson, Prof. Zadok	Vermont.
Stokes, William A	Pennsylvania.	Thomson, Prof. S. H	Indiana.
Stone, Isaac	Michigan.	Thornton, Miss E. E	New Jersey.
Stouffer, And	Minnesota.	Thornton, Dr. S. C	New Jersey.
Stowell, T. B	Kansas.	Thorp, Henry W	Md. and Penn.
Straetmans, H. I	Missouri.	Tidswell, Miss Mary A	Missouri.
Strang, J. J	Michigan.	Tingley, Prof. Joseph	Indiana.
Streng, L. H	Michigan.	Tirrell, Dr. N. Q	Massachusetts.
Strickland, L. S	Maine.	Titcomb, J. S	Illinois.
Strong, Edwin A	Michigan.	Titus, H. W	New York.
Strong, Oscar I	Iowa.	Titze, H. A	Illinois.
Strong, Rev. Thomas H	New York.	Toby, James K	Vermont.
Strunk, Daniel	Wisconsin.	Tolman, *J. W	Illinois.
Struthers, R. H	Wisconsin.	Tolman, Rev. Marcus A	Pennsylvania.
Stuart, E. W	Ohio.	Tompkins, W	New York.
Stuart, Prof. A. P. S	Nova Scotia.	Tooker, Nathan C	Pennsylvania.
Stumps, S. J	West Virginia.	Tourtellot, Dr. L. A	New York.
Stuntebeck, F. H	Missouri.	Tower, James M	New York.
Stuntz. G. R	Wisconsin.	Towers, M. H	Wisconsin.
Stuver, A. S	Ohio.	Townsend. Nathan	Iowa.
Suter, Captain C. R	South Carolina.	Towson, J. W	Ohio.
Sutherland, Norris	Missouri.	Tracy, George H	Pennsylvania.
Sutton, Rev. A	Maryland.	Tracy, James E	Pennsylvania.
Sutton, Dr. G	Indiana.	Travelli, J. I	Pennsylvania.
Swain, Dr. John	Illinois and Ky.	Treat, Samuel W	Ohio.
Swan, Caleb	New York.	Trembley, Dr. J. B	Ohio.
Swan, James G	Washington Ter.	Trevor, James B	New York.
Swart, Haren V	New York.	Trible, Miss Anna C	Illinois.
Swazey, C. B	La. and Miss.	Trivett, Walter M	California.
Swift, Lewis	New York.	Trowbridge, David	New York.
Swift, Dr. Paul	Pennsylvania.	Troy, Dr. M	Alabama.
Sylvester, Dr. E. Ware	New York.	True, H. A	Ohio
Talcott, H	Illinois.	* Tuck, Dr. W. J	Tennessee.
Tappan, Eugene	Massachusetts.	Tucker, Edward T	Massachusetts.
Tappan, E. T	Ohio.	Tuckerman, L. B	Ohio.
Tate, And	Wisconsin.	Tuomey, Prof. M	Alabama.
Tavel, B. F	Tennessee.	Turnbull, Lieut. C. N	Michigan.
Tayloe, E. T	Virginia.	Turner, A. P	Indiana.
Taylor, John	Pennsylvania.	Turner, David	Virginia.
Taylor, Joseph W	New York.	Turner, T. A	Texas.
Taylor, Prof. K. M	Iowa.	Tutwiler, H	Alabama.
Taylor, L. B	Louisiana.	Tweedy, D. H	Ohio.

*Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Twiss, Thomas S	Nebraska.	Wattles, J. O	Kansas.
United States consul	Bahamas.	Weast, J. W	Arkansas.
Ufford, Rev. John	Iowa.	Weatherford, John M	Missouri.
Underwood, D	Vermont.	Webb, Miss G	Mich. and Ind.
Underwood, Colonel D	Wisconsin.	Webb, Dr. Robert D	Alabama.
Upshaw, G. W	Virginia.	Weber, P	Missouri.
United States engineers	Michigan.	Webster, Prof. N. B	Virginia & N. C.
Vagnier, Thomas	Indiana.	Weeks, James A	Pennsylvania.
Valentine, John	Indiana.	Weir, A. D	Pennsylvania.
Valentine, Felipe	Costa Rica.	Weiser, R	Pennsylvania.
Van Blascom, J	Maine.	Wellford, B. R	Virginia.
Van Buren, Jarvis	Georgia.	Wells, C. B	Nebraska.
Van Doren, A	Virginia.	Wells, J. Carson	Virginia.
Van Horne, F. B	Indian Territory.	Wells, W	Missouri.
Vankekle, L	Delaware.	West, Edmund	Ohio.
Vankirk, W. J	Alabama.	West, E. W	Ohio.
Vankirk, W. J	Missouri.	West, L. W	Wisconsin.
Vankleek, Rev. R. D	New York.	West, Dr. N. P	Texas.
Van Nostrand, J	Texas.	West, Silas	Maine.
Van Orden, W	Michigan.	Westbrook, Samuel W	North Carolina.
Van Vorhees, A	Minnesota.	Westdahl, F	Alaska Ter.
Von Frantzius, Dr. A	Costa Rica.	Westmoreland, J. G	Georgia.
Verrill, G. W., jr	Maine.	Wetherill, Prof	New York.
Vertrees, John E	Missouri.	Wheaton, Alex. Camp	Iowa & Mon. T.
Vincent, J. H	Mississippi.	Wheaton, Mrs. Daniel D	Iowa.
Vogel, C	Missouri.	Wheeler, B. J	Vermont.
Waddell, William H	Mississippi.	Wheeler, John T	New Hampshire.
Wade, Edward	Ohio.	Whelpley, Miss Flor'e E	Michigan.
Wade, F. S	Texas.	Whelpley, Miss Helen I	Michigan.
Wadey, H	Iowa.	Whelpley, Dr. Thomas	Michigan.
Wadsworth, A. S	New York.	Whipple, Capt. A. W	Michigan.
Wadsworth, General P	Maine.	Whitaker, B	Illinois.
Wagner, W. H	Oregon.	Whitcomb, George	Missouri.
Wainwright, Elmore	Michigan.	Whitcomb, L. F	Massachusetts.
Waite, M. C	Wisconsin.	White, Prof. Aaron	New York.
Wakeley, C. C	New York.	White, Bela	Nebraska.
Walker, David, M. D	Vancouver's isl.	White, Prof. J. B	South Carolina.
Walker, J. P	Delaware.	White, Peter	Michigan.
Walker, Mrs. Mary A	Kentucky.	White, Dr. W. T	New Grenada.
Walker, Mrs. Octavia C	Michigan.	Whitehead, W. A	New Jersey.
Walker, R. L	Pennsylvania.	Whitfield, E	Minnesota.
Walker, S. C	Pennsylvania.	Whiting, Robert C	New Hampshire.
Wallace, Samuel J	Illinois.	Whiting, William H	Wisconsin.
Wallace, Colonel W	South Carolina.	Whitlock, James H	California.
Waller, R. B	Alabama.	Whitner, B. F	Florida.
Walsh, Stephen	Minnesota.	Whitney, Miss L. J	Georgia.
Walter, Dr. James	Kansas.	Whittlesey, C. S	Michigan.
Walton, Joseph P	Iowa.	Whittlesey, S. H	Michigan.
Ward, Rev. L. F	Ohio.	Wickline, Thomas J	Virginia.
Ward, Prof. W. H	Wisconsin.	Wieland, C	Minnesota.
Warder, A. A	Ohio.	Wieland, H	Minnesota.
Warder, R. B	Ohio.	Wiessner, J	Dist. Columbia.
Waring, Prof. C. B	New York.	Wiggin, Andrew	New Hampshire.
Warne, Dr. George	Iowa.	Wilbur, B. F	Maine.
Warren, James H	New York.	Wild, Rev. Edward P	Massachusetts.
Warren, James H	Iowa.	Wilkinson, C. H., M. D	Texas.
Washburn, D	Pennsylvania.	Wilkinson, John R	Ohio.
Washington, L	Wisconsin.	*Willard, J. F	Wisconsin.
Watkins, W. D	Ohio.	Willet, Prof. J. E	Georgia.
Watson, George	New Jersey.	Williams, B. C	Illinois.
Watterson, H. R	Ohio.	Williams, Ed. F	Tennessee.
Wattles, Miss Celestia	Kansas.	Williams, H. B	Iowa.

* Deceased.

List of meteorological observers, &c.—Continued.

Name.	State.	Name.	State.
Williams, Prof. J. R	Pennsylvania.	Woodruff, E. N	Kentucky.
Williams, Prof. L. D	Pennsylvania.	Woodruff, L	Michigan.
Williams, Prof. M. G	Ky. & Ohio.	Woods, W	Wisconsin.
Williams, Dr. P. O	New York.	Woodard, C. S	Michigan & Ind.
Williams, Rev. R. G	N. Y. & Conn.	Woodard, C. S	New York.
Williams, Rev. S. R	Kentucky.	Woodward, Lewis	New York.
Williams, Prof. Wm. D	Georgia.	Woodworth, Dr. A	Kansas.
Willis, Henry	Maine.	Woodworth, Samuel	Iowa.
Willis, O. R	N. Y. & N. J.	Woolsey, Dr. W. W	Iowa.
Willis, P. L	Oregon.	Wooster, C. A	New York.
Wills, J. C	Virginia.	Wormley, Theo. G	Ohio.
Wilson, G. W., jr	Missouri.	Wray, Alex	North Carolina.
Wilson, Joseph A	Missouri.	Wright, Dr. Daniel F	Tennessee.
Wilson, Dr. J. B	Maine.	Wright, E. M	Minnesota.
Wilson, Prof. J. H	Ohio.	Wyman, A. H	Maine.
Wilson, Lavallette	Massachusetts.	Wyrick, M. L	Missouri.
Wilson, P. S	Missouri.	Yale, Walter D	New York.
Wilson, Prof. W. C	Pennsylvania.	Yellowby, Prof. C. W	Texas.
Wilson, Rev. W. D	New York.	Yeomans, W. G	Connecticut.
Wilson, W. W	Pennsylvania.	Yoakum, F. L	Texas.
Winchell, Prof. A	Ala. & Michigan.	Yoakum, H	Texas.
Windle, Isaac E	Indiana.	Young, A. A	New Hampshire
Wing, M. E	Vermont.	Young, Prof. C. A	Ohio.
Winger, Martin	Ohio.	Young, Prof. Ira	New Hampshire
Winkler, Dr. C	Wisconsin.	Young, J. A	South Carolina.
Wise, John	Pennsylvania.	Young, Jude. M	New York.
Wislizenus, Dr. A	Missouri.	Young, Mrs. L	Kentucky.
Withrow, Thomas F	Ohio.	Younger, Armistead	Arkansas.
Witter, D. K	Iowa.	Younglove, J. E	Kentucky.
Woodbridge, W	Indiana.	Zaeppfel, J	New York.
Woodbury, C. E	Minnesota.	Zahner, P	Nebraska.
Woodbury, C. W	Minnesota.	Zealy, Joseph T	South Carolina.
Wood, Samuel	New Jersey.	Zeigler, Dr. A. F	Idaho Territory.
Wood, S. B	Ohio.	Zimmerman, G	New York.
Woodbridge, W	Indiana.	Zumbrock, Dr. A	Maryland.
Woodin, S. F	New York.		

METEOROLOGICAL MATERIAL CONTRIBUTED IN ADDITION TO THE REGULAR OBSERVATIONS, DURING THE YEAR 1868.

Académie Impériale de Lyon.—Mémoires de l'Académie Impériale des Sciences, Belles-Lettres et Arts de Lyon, classe des sciences, tome seizième, Lyon, 1866–'67, 8vo., 446 pages. [Contains: Observations Météorologiques faites à 9 heures du matin à l'observatoire de Lyon du 1er Décembre 1865, au 1er Décembre 1866, par M. Aimé Drian, sous la direction de M. Lafon, professeur à la Faculté des Sciences et directeur de l'observatoire, 26 pp. Résultats de la nouvelle série d'observations ozonométriques faites par MM. le Docteur Lembert et F. Rassinier, durant l'année 1866, 32 pp. Classification des phénomènes produits par l'électricité météorique dans le bassin du Rhône et aux alentours, par M. J. Fournet, president de la commission des Orages, lue dans la séance du 6 Mars 1867, 122 pp.]

Aguilar, F. C.—Boletino Meteorologico del observatorio del Colegio Nacional de Quito, dirigido por los padres de la Compañia de Jesus, segundo año 1866, F. C. Aguilar, S. J., Quito, 1868, 36 pages, 8vo.

Asiatic Society of Bengal.—Journal, Part II, No. II, 1868, containing abstract of the results of meteorological observations taken at the surveyor general's office, Calcutta, September, 1866, to June, 1867, inclusive; also tables of mean monthly readings of the barometer reduced to freezing point, for 10 years, from 1856 to 1865, and of barometric curve and registered rainfall.

Bache, R. M.—Notes on the climate of San Francisco, California, and table of temperature.

Berkey, W. H.—Meteorological record kept at Ossawatomie, Kansas, during the month of March, 1868.

Boardman, G. A.—Meteorological observations made during the month of January, 1868, at Green Cove Spring, Florida.

Boerner, Charles G.—Account of the meteoric shower of November 13 and 14, observed at Vevay, Indiana.

Bruhns, Dr. C.—Resultate aus den Meteorologischen Beobachtungen angestellt an mehreren Orten im Königreich Sachsen in den Jahren 1826 bis 1861, und an den fünfundzwanzig Königlichen Sächsischen Stationen im Jahre 1866. Nach den monatlichen Zusammenstellungen im Statistischen Bureau des Königlichen Ministeriums des Innern, bearbeitet von Dr. C. Bruhns, Director der Sternwarte und Professor der Astronomie in Leipzig. Dritter Jahrgang, Leipzig, 1868, 4to, 136 pp.

Bush, Richard J.—Meteorological observations made during the exploration of the country between Okhotsk and Nicolaefsk, East Siberia, in the service of the Western Union Telegraph Company, October 21, 1865, to March 4, 1866.

Chase, Pliny Earle, Philadelphia.—Curves indicating the relation of the moon to temperature at the surface of the earth.

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Waller, Robert B.—Meteorological observations made at Greenesboro', Greene county, Alabama, during the year 1862.

Walton, J. P.—Account of meteors, November 13, 1868. (Newspaper slip.)

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Williams, B. C.—Thermometrical record for the month of February, 1868, at Ridge farm, Vermillion county, Illinois.

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REPORT OF THE EXECUTIVE COMMITTEE.

WASHINGTON, *January* 14, 1869.

The Executive Committee of the Smithsonian Institution respectfully submits the following statements in relation to its invested capital, the receipts and expenditures during the year 1868, and an estimate of receipts and proposed appropriations for 1869:

CAPITAL INVESTED.

The Smithson fund in the Treasury of the United States on the 1st of January, 1869, remains as stated in the last annual report		$650,000 00
And in Virginia State 6 per cent. bonds	$53,500	
With coupon bonds issued for unpaid interest to January, 1867	19,260	
	72,760	
The value of which at the present time may be estimated at 55 per cent. on the par value		40,018 00
Total invested capital		690,018 00

RECEIPTS IN 1868.

Interest from the Treasurer of the United States on $650,000 at 6 per cent. for the year ending 31st December	$39,000 00
Premium on sale of gold	14,527 50
Interest on Virginia 6s, old bonds, 2 per cent. on $53,500 for the first six months of 1868, less brokerage	1,067 33
From sales of publications	385 52
From sales of old and useless material	188 88
Repayment of expenses of explorations from parties co-operating with the Institution	698 54
Repayment for freights incurred on account of parties sending books to foreign libraries	100 00
Cash balance in bank, January, 1868	11,485 56
Amount available for 1868	67,453 33

In addition to this amount the Institution received from, and accounted for, to the Department of the Interior, the sum of $5,116 31, appropriated by Congress for the preservation and care of the property in the museum collected by government exploring expeditions. Of this sum $4,000 was the appropriation for the year 1868–'69, and $1,116 31 the balance of the previous year's appropriation.

The State of Virginia paid during the year 2 per cent. on its old bonded debt for the first six months, leaving 1 per cent. still due for that period, claimed to be payable by Western Virginia, as a just proportion of the original State debt. On its new bonds, issued for coupon interest past due, nothing has been paid. The State proposes to sell its interest in certain canals, rail and other roads, to liquidate this and other indebtedness, and favorable results may for the future be anticipated from this investment.

Statement in detail of expenditures during the year 1868

BUILDING.

For the reconstruction of parts of the building destroyed by fire, completed in 1867 and paid in 1868	$18, 457 20	
Repairs of other parts of the building	2, 746 49	
Furniture and fixtures to meet the general wants of the Institution	2, 982 38	
Amount expended on the building		$24, 186 07

GENERAL EXPENSES.

For meetings of the Board of Regents	$303 37	
Lighting the building, offices, &c	276 35	
Warming the building, offices, &c	1, 086 50	
Postage	456 89	
Stationery	345 92	
Printing labels, blanks, circulars, &c	189 81	
Tools, materials for cleaning, binding records, &c., &c.	614 70	
Salaries of secretary, chief clerk, and assistants, laborers, and contingent labor	9, 552 80	
Interest on temporary over-draft	72 00	
		12, 898 34

PUBLICATIONS, RESEARCHES, &C.

Publishing transactions, researches, &c., for Smithsonian Contributions, quarto	$4, 633 09	
Miscellaneous collections, octavo	1, 177 45	
Smithsonian reports, illustrations, stereotyping, &c., octavo	1, 050 75	
Meteorology, computations, &c	1, 011 47	
Apparatus	99 70	
Explorations, natural history, and archæology	1, 682 57	
		9, 655 03

LIBRARY, MUSEUM, AND EXCHANGES.

For purchase of books and binding	$775 42	
Literary and scientific exchanges	2, 801 84	
Assistants in museum, janitor, watchmen, laborers, and for labelling and arranging shells and ethnological specimens	3, 226 72	
Incidentals for museum—alcohol, bottles, &c	1, 488 29	
Freight on books, specimens, and other property received and sent away	2, 068 88	
		10, 361 15
Expenditures during the year		57, 100 59
Deducting this amount from the receipts of the year and cash in bank on 1st January, 1868, as previously stated	$67, 453 33	
Leaves a balance in bank January, 1869, of		$10, 352 74

EXAMINATION OF ACCOUNTS.

The committee has examined 576 receipted vouchers for payments made during the four quarters of the year 1868. Evidence of the receipt of materials and property, and of services rendered, and payment to the claimants or legal representatives, was found for the whole amount expended during the year. An examination of the quarterly accounts current, bank-book, check-book, and ledger showed that the payments were made as required by the regulations prescribed by the regents; and the cash balances stated in the accounts current were in the authorized depository after the payment of all the quarterly accounts charged in the abstracts of expenditures.

In the receipts for the year 1868, the sum of $5,116 31 is noted as having been received through the Department of the Interior, appropriated by Congress for the preservation and charge of its property in the museum collected by government exploring expeditions. The expenditure of this sum was made and accounted for in strict conformity with the financial regulations prescribed by the regents.

ESTIMATED RECEIPTS FOR 1869.

Interest on the Smithsonian fund in the treasury of the United States $650,000, payable 1st July, 1869, and 1st January, 1870, at 6 per cent. in gold	$39, 000 00
Probable premium on sale of coin	13, 000 00
Interest on Virginia 6 per cent. stock	1, 067 00
Sales of useless property and other incidental sources during the year	500 00
Total income in 1869	53, 567 00

APPROPRIATIONS FOR 1869.

It is proposed to apply the income of the year as follows:

For general expenses	$15, 000 00	
Publications and researches	15, 000 00	
Library, collections for museum, and exchanges	10, 000 00	
Continuing the repairs of the building	5, 000 00	
	45, 000 00	
Leaving from the yearly income a balance of	8, 567 00	
		$53, 567 00

It will thus be seen that the Institution has paid all its indebtedness; provided all needful accommodation in the gradual reconstruction of parts of its building destroyed by fire; published large editions of annual contributions to science; accumulated a saving from its income of 1868 of $10,352 74, and an estimated saving of $8,567 from its income of 1869—making the sum of $18,919 74 as an available fund in January, 1870, to enable the Institution to conduct its operations on a cash basis from the beginning of the year, and to continue and extend its investigations in the various branches of physical science; at the same time supplying apparatus for warming the various apartments in the building.

RICHARD DELAFIELD,
PETER PARKER,
Executive Committee.

WASHINGTON, *January*, 14, 1869.

JOURNAL OF PROCEEDINGS

OF

THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION.

WASHINGTON, *January* 20, 1869.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of beginning of the annual session on the third Wednesday of January in each year, a meeting was called for this day.

No quorum being present, the board adjourned to meet on Wednesday, 27th January, 1869, at 7½ o'clock.

WASHINGTON, *January* 27, 1869.

A meeting of the Board of Regents was held at 7½ o'clock p. m. at the Institution. Present, Hon. B. F. Wade, Hon. W. P. Fessenden, Hon. L. Trumbull, Hon. G. Davis, Hon. J. A. Garfield, Hon. J. V. L. Pruyn, Hon. R. Delafield, Hon. P. Parker, Rev. Dr. John Maclean, Hon. S. J. Bowen, and Professor Henry, the secretary.

Mr. Wade was called to the chair. The minutes of the last meeting were read and approved.

The secretary stated that since the last session, Mr. Sayles J. Bowen had been elected mayor of the city of Washington, and thereby became ex-officio a member of the board in place of Mr. Wallach, and that Professor Agassiz's term had expired, but a resolution reappointing him a Regent had passed the Senate.

General Delafield, in behalf of the Executive Committee, presented the annual account of receipts and expenditures for the year 1868, with estimates for the year 1869; which was read, and,

On motion of Mr. Pruyn, the report was adopted.

General Delafield also presented the following report relative to the Washington city canal, which was read:

Report of the executive committee on a resolution of the Regents of the Smithsonian Institution on the influences of the Washington city canal on the health of the population of the city, May 15, 1868.*

The executive committee, to which was referred the resolution of the Regents of the Smithsonian Institution of the 22d of April, 1868, instructing it to ascer-

* Senate Mis. Doc. No. 95, 40th Congress, 2d session.

tain what measures are proposed to be taken by the city authorities of Washington in regard to the canal, so far as concerns the Smithsonian Institution, has examined the subject and now report, for the information of the Regents:

That the Washington city canal has been constructed under the authority granted by the following laws:

On the 1st of May, 1802, Congress passed an act incorporating the Washington Canal Company, to raise $80,000, and construct a canal from the Potomac to the Eastern Branch, to admit boats drawing three feet water to pass through the whole extent of said canal, with the right to charge and collect tolls and wharfage. If not so completed within five years, it was to revert to the United States.

This act seems to have expired by the failure of the company to execute the work, and on the 16th of February, 1809, Congress incorporated other parties, to raise $100,000, with the same title, to construct the canal through part of the city of Washington, as laid down on a plan of the city defining its limits, to admit of boats drawing three feet water to pass through it; and if, at any time, the canal shall become obstructed so that boats and scows drawing three feet water cannot pass through from the Potomac to the Eastern Branch, the company shall not collect tolls or wharfage, and all the rights under this act shall cease, unless the canal is completed within seven years from the passage of the act.

Before the expiration of this seven years, and on the 6th of May, 1812, Congress authorized money to be raised by lottery for completing the canal, rendering it navigable, and draining the marshes and low grounds contiguous thereto, and on the 7th of May, 1822, authority was granted by Congress *to the city* of Washington to contract with the canal company to change the direction of parts of the canal, to drain and dry the low grounds on the borders of Tiber creek.

On the 20th of May, 1826, the canal company was authorized to increase the width of the canal along the present boundary of the Smithsonian grounds, and elsewhere, to 150 feet in width, and also to construct basins; and within five years shall construct the canal through its whole length to contain water at least *one foot* in depth at ordinary low water.

On the 2d of May, 1831, the canal company sold all its interest to the city of Washington, which was conveyed by a deed dated the 23d of July, 1831; and on the 31st of May, 1832, Congress confirmed this sale, and enacted that all the right, title, interest, property, and estate of the Washington Canal Company are vested in the mayor, aldermen, and common council, for the aforesaid use, with the *proviso*, that the canal shall be finished and completed, of the breadth and depth and in the manner and within the time hereinafter prescribed, and not otherwise. The act then prescribes the width at different parts, and then that the canal, throughout its whole length and breadth aforesaid, and the basins, shall have a depth of *at least four feet water at all times*, and that the whole shall be walled on its sides, and made suitable for steam-vessels, to be used therein, and finished by the 1st of March, 1833, and in default, all the rights and privileges granted by this act shall cease and determine. No tolls or wharfage were allowed to be charged or collected whenever the canal was so out of repair as to impede the free navigation with four feet water. By the same act all the right, title, property, interest, and estate of the United States, of, in, and to that part of the public reservation designated as the mall, was vested in the city corporation, in fee, to be sold, and the moneys applied to the construction of the canal. A street of 80 feet wide on the south side, in addition to the 40 feet landing, was also authorized, and previous specified acts, conflicting with this act, were repealed.

On the 2d of March, 1833, Congress appropriated $150,000 to aid in fulfilling the objects and requirements of the act of 31st of May, 1832, provided the city corporation relinquished all title to the land vested in it by the 8th section of

the act, and all the rights and privileges granted by the 8th, 10th, 11th, 12th, 13th, and 14th sections of said act.

On the 3d of March, 1849, Congress appropriated $20,000 for clearing out and deepening that portion of the canal which passes through and along the public grounds, provided the city expends a like sum in cleaning out and deepening the other portions.

On the 3d of March, 1851, Congress appropriated $20,000 for completing, clearing out, and repairing that portion of the canal which passes through and along the public grounds, provided the city expends a like sum in clearing and repairing the other portions.

On the 23d of February, 1865, Congress authorized the city corporation to lay taxes * * to introduce the necessary *sewerage and drainage facilities* under or upon the whole or any portion of any avenue, street, or alley.

On the 16th of February, 1866, a bill was reported in the House of Representatives creating a sewerage commission, with power to improve and regulate the Washington city canal, as may be necessary; and on the 6th of March an amendment to the bill of the 16th of February, 1866, was reported, limiting the number of commissioners to three, giving them power to adopt and lay down a complete and uniform plan of sewerage, as it may deem necessary and most advisable, with reference to the public health and general interest; the city to raise $150,000 to execute the work by contract, and the United States not to be responsible for an amount exceeding one-half the outlay or expenses incurred under this act. There was no further action on this bill or amendment.

About the same time, to wit, on the 7th of March, 1866, the Senate of the United States passed a resolution requiring the appointment of a board of United States engineers, to report a plan for improving the *canal and sewerage* of the city. This board, on the 2d of April, 1866, made a partial report for the temporary improvement of the *canal*, which the city authorities adopted, and appropriated $75,000 to carry into effect.

Such is all the legislation on this subject the committee has been enabled to find, up to the end of the year 1867; from which it appears the United States granted to a company the right to construct the canal in question, on certain conditions and for specified uses; that this company sold all its rights to the corporation of the city of Washington, and the United States approved the sale and transfer, granted additional rights, and exacted additional facilities, limiting the uses to navigation by steamers, barges, and scows over the whole surface and length of the canal and basins, from the Potomac to the Eastern Branch. No authority is found for converting the canal into a sewer or recipient for the sewerage matter of the city, nor can the committee find that the purposes of the canal for navigation have ever been carried into full effect. It would further appear that the city can make no sale, transfer, disposition, or change of its rights, interests in and uses of the canal, without the authority of the United States, and it may well be questioned whether or not the city has lost all its rights in the premises, by failing to make the canal navigable, and using it as a sewer and reservoir for the excreta from a large proportion of the population of the city.

PROPOSED ACTION.

On the 6th April, 1868, a bill was reported in the board of aldermen, granting to certain citizens all the rights now held by the city in the canal for a term of 30 years. It proposes to grant, for the sole use and benefit of the parties named, all the rights, &c., of the city to the canal, and all the rights conferred by the United States, under the act of the 31st May, 1833. The corporators are to narrow the existing canal, and deepen it to *one foot* at *low water*, and finish the same in June, 1873, and may collect tolls and dockage. The company shall extend all sewers now leading into said canal to the outer surface of the canal

wall, and at no time interfere with the canal being used for sewerage. It was provided that this transfer, with the proposed modifications, be submitted to Congress for approval.

The mayor of the city, in a communication to Congress of the 23d April, 1866, states that the condition of the canal is such as to require an abatement of the *nuisance* caused by deposits from the sewers, while the bill now under consideration of the council greatly increases and prolongs this nuisance.

The committee concurs in the opinion of the mayor of the city that the proposed grant of the canal to a private corporation would be a grievous injury to the inhabitants of the city, and would defeat the much-desired object of both Congress and the community of securing the health of the city.

The committee learns from the mayor that it is proposed to extend the Chesapeake and Ohio canal from Georgetown, through the city, to the deep water along the Eastern Branch, with the view of establishing a shipping port for large vessels, and depot for the Cumberland coal, thus sharing with Georgetown and Alexandria the profits of this branch of industry. The project is one to which the committee should present no objection, provided it does not interfere with the general health of the city, or works necessary for promoting the health of the inhabitants.

The committee considers that a canal for such a purpose, or any other, through this city, should not lock down to tide-water until it has passed entirely through the city, and recommends that neither the existing canal, the proposed modifications, nor transfer of the existing canal to any private corporation, be approved by Congress unless the subject of public health and sewerage be first provided for, and insured against all hindrance and interruption for all time to come, and that no sewage matter be allowed to enter *any open canal whatever*, within the limits of the District of Columbia.

INFLUENCE OF THE CANAL ON THE HEALTH OF THE POPULATION.

At the present time the Washington city canal is an extended cesspool, the bottom of which is below the level of low water, the surface varying with the slow and gradual rise and fall of the tide, without any current to act upon the bottom or of sufficient velocity to move insoluble ponderous matter that is received into it.

The sewage from the water-closets, kitchens, laundries, stables, cattle-pens, and street gutters is now received into this immense trap, there to remain, without power of any kind to carry it into the river or other place to protect the city against its pernicious effects and influences. The existing sewers now enter this reservoir so much below low water as to have caused one-half their entire height to be closed by deposit, and as a consequence filling every such sewer with poisonous matter into the city to the level of the intersection of the water in the canal with the inclined plane of the bottom of the sewer. This mass cannot be removed by any means now available. On the supposition that the canal receives the sewage from a population of only 30,000 of the inhabitants of the city, the estimated annual cubic mass that is thrown into the canal is not less than 300,000 cubic feet, or at the rate of 10 cubic feet per head per annum of solid and fluid human excrement.

This fecal matter has for some years past been accumulating in the canal, in proportion to the extent and number of sewers constructed from time to time, without any power of removal of the solid parts, and only a slight power for moving the fluid portions backwards and forwards, there being no continuous current to force even the fluid and soluble parts into the Potomac or Eastern Branch.

From the experience of other cities, and the investigations of chemists and engineers, we learn that open sewers, as the canal in this city, evolve gases very

prejudicial to health. Observation has shown that the death rate is much greater among the population along these open sewers than in streets removed but a short distance from them.

The signs of animal life visible to the naked eye in small rivers after receiving sewage matter consists of myriads of minute worms, characteristic of all sewage water, and may be regarded as the last remains of animal life which can survive in such a locality; and even these die off in summer.

The putrescence of the organic liquids and deposits in the open sewers and bottoms and beds of streams in all weathers, and the evolution of noxious gases therefrom, lead to the sensible contamination of the surrounding atmosphere, and consequently decreases the purity and healthiness of the air, and the discharge of sewage matter into streams and small rivers pollutes the water by the mixture of much organic matter in a state of active putrescence.

Analysis gives 15 to 80 grains per gallon of suspended matter, and from 35 to 76 grains of dissolved matter, of the sewage of large towns. Of the former about 35 per centum is organic, and of the latter about 28 per centum. The organic matter consists of vegetable and animal fibre with a soluble extractive in a high state of decomposition. The organic constituents give off such an abundance of foul gases that they are a constant source of annoyance. These gases consist of about 73 per centum of light carburetted hydrogen, 16 per centum of carbonic acid, 10 of nitrogen, and traces of sulphuretted hydrogen, ammonia, and a putrid, organic vapor that is in the highest degree offensive.

Every gallon of sewage will discharge from $1\frac{1}{4}$ to $1\frac{1}{2}$ cubic inches of this gas per hour, and the fermentation continues for weeks. Whenever this gas escapes from privies, cesspools, or sewers, it causes disease, and finally sets up a putrid form of fever which is exceedingly fatal.

Every effort is made elsewhere to prevent the diffusion of these fœtid gases into the houses and public ways, while in Washington we promote the evil to an incalculable extent and danger in that vast fermenting vat, the city canal.

It follows that the sewage of large populous cities and towns can only be conducted into large rivers near the sea, that they may not contaminate the atmosphere, and should never be discharged into fresh-water streams used or required for man or beast.

If conducted into closed harbors or bays, they create such a deadly pollution as soon to lead to the most alarming consequences.

The magnitude of this evil, and the suddenness with which it may come upon us in its most fatal form, are exemplified by the experience of London. The committee asks attention thereto, as fully illustrating the evil we have to combat in this city, and the necessity of prompt attention:

"On the introduction of the water-closet system in London, and the abolition of cesspools, with the increase of gas-works, the Thames began to give indications of receiving a larger quantity of decomposing matter than it could purify or get rid of by the tide movement. In 1856 it became apparent in the summer months that the river emitted a disagreeable stench. This became still more evident in 1857, and was obviously dependent on the increased attention paid to the removal of all refuse from houses by the aid of drainage. In 1858 the stench appeared with increased intensity, and especially in the neighborhood of the new houses of parliament. Every one felt it was necessary to meet so gigantic an evil. The river had become one elongated cesspool, and the effect upon the teeming population of its banks might be in a short time of the most disastrous kind. In 1858 an act was passed for preventing, as far as practical, the sewage from passing into the Thames within the metropolis, giving authority to expend three millions of pounds sterling to effect the object."

This experience may very properly be received as a truthful representation of what is being done in this city, and the consequences.

The specific gravity of sewage gases is lighter than that of the atmosphere

Generated in large volumes in the canal, and lower end of as well as in the sewers, it ascends the sewers to escape at every higher level, and creates the pestilential influences heretofore referred to. We had some experience in this city in 1857, causing death and prolonged disease among the inmates of one of our hotels. Thus the deleterious gases ascend and the poisonous liquids descend, making the ventilation of the sewers as important as conveying away the solids and liquids to insure the health of the city. No system of cleansing sewers by manual labor is justifiable.

Laborers employed in this disgusting business in the culverts for fluid excrements, as in the Paris system, are subject to two terrible diseases, both due to the deadly effluvium of fæces, the one caused by ammonia gas, creating distempers of the nose and eyes, and the second by sulphuretted hydrogen, nitrogen, and hydrosulphuretted ammonia, causing sudden death. In the sewers for fluid and solid excrementa, as in London and Washington city, the effects are even more fatal. In the report of the engineer relating to the London sewers, it is stated that he witnessed several cases of death, and others in which men were taken out insensible, after only a few seconds' exposure. In Warwick street, Pimlico, five men were killed, in 1852, by this gaseous sewage. Three of them had gone into the sewer early in the morning, and, not returning for breakfast, alarm was felt for their safety. A surgeon entered the sewer and was killed on the spot. A young policeman followed and was struck dead in a few minutes. On examination after death it was shown that he could not have made more than two respirations before death after entering the sewer. On making an opening from the street into the sewers to get the bodies of these men, the gases as they escaped were set fire to by a match and burnt with a yellow flame, rising twenty feet. Within three months of the date of the engineer's report three more lives were lost near Whitechapel by breathing sewage gases as it escaped from an opening made into another sewer.

It is now a well-established fact, deduced from the medical statistics of the English armies in India, and of our army in its marches during the past two years, that cholera is propagated mainly by atmospheres contaminated and poisoned by the excrement of cholera patients.

In this city the canal would be the reservoir for such matter, first to be contaminated by travellers from infected districts, sojourning temporarily at the hotels, all the sewers from which now or are hereafter to empty in the canal.

The committee is of the opinion that the canal, as it now exists, is a great cause for creating and propagating disease, and should at the earliest possible moment be filled up and discontinued for use as a sewer and reservoir for excrement and waste waters of kitchens, water-closets, laundries, and other sources of contaminating matter, and is also of the opinion that, if the proposition of granting the city rights to this canal be confirmed, the evils herein set forth cannot be efficiently corrected by any means left in the power of the public authorities without incurring a heavy expenditure to purchase rights and property now proposed to be given away.

It is proper to state that part of this system of sewage, and, it is believed, the commencement of making the canal a reservoir and cesspool, was made under appropriations of Congress for building sewers from the Capitol and the executive buildings from Fifteenth to Seventeenth streets.

REMEDIES FOR THE EXISTING EVILS.

The committee has pointed out the probable evil consequences of our existing system of sewage, as a result of using the canal as a cesspool and reservoir for the fecal matter, from whence it cannot be removed by any existing means. It has also shown that the air and water from the canal are contaminated by the sewerage of the city, and produce fatal diseases tending to virulent epidemics, and that the canal is neither fit for navigation, sewerage, or drainage, in its present form and dimensions.

It remains for the committee to propose some method by which these evils may be remedied.

The old, thickly populated cities and towns of Europe have been compelled, for self-preservation, to expend millions of money, and adopted a variety of systems to remove excrement from the limits of their abodes.

The systems last adopted for Paris and London, at an immense outlay, give in general the main reliable features of the most acceptable plans.

In Paris metallic vessels for every family are so arranged that the solid fæces are separated from the urine. The latter passes into street sewers of large dimensions, conducting it, with the surface drainage from the streets, into the Seine, and the solids are removed from the dwellings by scavengers with carts, and conveyed some miles from Paris, where it is converted into dry poudrette and sold for manure. No less than 278,000 cubic metres of these solid excrementa were collected from the tenements in Paris and removed to La Vilette for conversion into fertilizing matters in one year.

In London a system commenced in 1859 of sewers at different levels, running parallel with the Thames, receives all the house and street drainage, both solid and fluid, and conducts the same, miles below the city, into the river, to find its way to the sea. These longitudinal sewers drain the entire city surface of 117 square miles, and are together 82 miles in length. Their fall does not exceed two feet per mile, and are carried over rivers, railways, roads, and streets, by wrought-iron aqueducts. Of the surface thus drained 25½ square miles are below the level of high water, and drained by a sewer of 10 miles in length. A part of the sewerage, or 14½ miles of this surface, has to be pumped up 17½ feet to discharge it into the Thames; and at what is called the Abbey Mills Station, the whole mass of sewage is pumped up 36 feet to the level of the outfall sewer. This system is peculiar in having culverts parallel with the river, to receive the sewage at high levels as far as practicable, and not allow it to fall into basins or valleys below the river surface, and by steam pumps raising all the sewage matter from surfaces below the river level into the main drains leading to the river.

Another system is advocated, by which all the excrementa is received from the water-closets, both solid and fluid, into small boxes in the streets, from whence it is drawn by pneumatic portable engines into tight barrels, and thence in its liquid state distributed in drills underground by ploughs, as a manure for the surrounding country. It is claimed to be the only effectual way of removing this offensive matter and preserving the whole of it for manuring the soil.

With subsoil ploughing, rotation of crops, lime, marl, green sand, barn-yard manure, guano, and other fertilizers, the use of sewage matter is not likely to be acceptable to our agriculturists, and no demand will probably exist sufficient to absorb the quantities that by this system must be daily disposed of in summer and winter.

The committee has come to the conclusion that we must construct the sewers of the city of Washington on levels *above high water*, and conduct them to discharge their contents in the strong *ebb current* of the Potomac river at *high water*, that the entire accumulation of twelve hours may have six hours of ebb tide to carry it towards the Chesapeake, which, with the annual freshets and constant flow of the Potomac, will always carry it beyond the distance it can be brought back by the flood.

It is indispensable the outlet of these main sewers should be *below the Long bridge*, (and as distant as practicable,) otherwise all the solid matter would accumulate on the shoals between this bridge and Georgetown, and in time create as great an evil as the canal.

To effect this object all the main sewers must be *carried across the site of the present canal* on *closed aqueducts or causeways*, at the most advantageous levels above high water, and thence under the grounds south of the canal, to suitable places on the bank of the river, where closed and covered reservoirs may be con

structed to retain the sewage until the ebb-tide makes, when gates or valves will be opened to allow it to escape into the river, under the water surface, using the waters of Rock creek and the Tiber to cleanse them.

The present canal should then cease to be used for any other purpose than as an escape for the waters of the Tiber during extraordinary freshets, and for such surface drainage as cannot be carried across it into the sewers leading to the Potomac, and to this end must be filled up and reduced in size and form to an arched culvert. The proposed canal for commercial purposes, with an outlet in the Eastern Branch, should, in like manner, be carried over the valley of the present canal on an aqueduct or causeway, and then through or along the high ground to the Eastern Branch.

We have found that the canal is not useful for navigation. A railroad over the same ground, extended along the river front, with turn-outs and sidings to warehouses and depots, free to every owner of a car, would better subserve the public welfare, it is believed, than any water transportation that can be derived from the existing or other canal. Such a road for heavy traffic, with a well-constructed paved street for light vehicles, and a paved walk along the south side, adjacent to the public reservations, connecting the Capitol, botanic garden, Smithsonian, agricultural, and Washington monument grounds with the grounds about the President's house, would insure greater health, promote public convenience, and greatly enhance the value of property now separated from the settled portions of the city by an impassable barrier. These are additional considerations for using the site of the existing canal as a covered drain or culvert for surface water only.

The committee has confined itself to pointing out the evil effects of the existing sewerage, the necessity for immediate correction, and a general plan therefor, leaving it for the talent and genius of the most experienced engineers to select the most advantageous sites for the outlets of the sewers, at the most *distant points* from dense population, and mature the details of a project for carrying this system into effect.

All of which is respectfully submitted by

RICHARD DELAFIELD,
For the Committee of the Regents.
RICHARD WALLACH, *Mayor.*
RICHARD DELAFIELD, *U. S. Army.*
PETER PARKER, M. D.

WASHINGTON, D. C., *May* 15, 1868.

After discussion, and the unanimous expression of opinion that the canal was a nuisance which should speedily be abated, on motion of Mr. Pruyn the following resolution was adopted:

"*Resolved*, That the report of the executive committee be accepted, and that the committee be authorized, in their discretion, to unite with the corporate authorities of Washington in a memorial to Congress for such relief as may eventually lead to an abatement of the nuisance complained of."

On motion of General Delafield, it was

"*Resolved*, That the vacancy in the executive committee be filled by the election of Rev. Dr. John Maclean."

Professor Henry presented his annual report of the operations of the Institution during the year 1868, which was read, accepted, and ordered to be presented to Congress.

On motion of General Garfield, it was

"*Resolved*, That the regents renew their application to Congress to increase the annual appropriation for the care of the government collections to $10,000."

The board adjourned, to meet at the call of the secretary.

GENERAL APPENDIX

TO THE

REPORT FOR 1868.

The object of this appendix is to illustrate the operations of the Institution by reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

MEMOIR OF CUVIER.

By M. Flourens.

*Translated for the Smithsonian Institution by C. A. Alexander.**

When a nation loses one of those men whose sole name would suffice for its own glory and that of an epoch, the grief which it feels is so profound that voices are raised on all sides to deplore the common calamity. There is a general emulation to pour forth the public regret at their tomb; a universal impulse to make known all that can be learned respecting lives so illustrious and so honorable to humanity.

So it should have been, and so in effect it has been in regard to M. Cuvier. Men of science, men of letters, whole Academies, indeed, have already published accounts of his life and person, and it would be too late to-day for the Academy of Sciences to say anything new of the great man whom it has lost. But, among the labors on which rests his renown, there are such as pertain more specially to this Academy, and the study of which is far from being exhausted. I allude to the progress which the natural sciences owe to M. Cuvier, a progress which has renovated all those sciences, and which has so greatly extended them that it has in reality extended, through them, the reach of the human mind and the domain of genius.

In M. Cuvier, therefore, I consider here only the savant, and even in the savant shall, above all, consider the naturalist. Fontenelle said, in his account of Leibnitz, that he had been obliged, in some sort, to divide and decompose that great man; and that quite the contrary of antiquity, which had made one Hercules out of many, he had made of Leibnitz alone, many savants. So it is necessary to decompose M. Cuvier, if we would at all measure his genius; this great intellect which, like that of Leibnitz, "conducted all the sciences abreast," and which, not restricting itself to the sciences, diffused its light on the highest institutions of the state, requires, in order to be properly comprehended, as many separate discussions as it has manifested different capacities. I repeat, therefore, that I here consider in M. Cuvier only the naturalist; but even so, my task will be immense, and, in venturing to approach it, I need all the indulgence of those to whom I address myself.

The history of M. Cuvier, if we recall all that the natural sciences owe to him, is scarcely less in fact than the history of those sciences in the earlier part of the nineteenth century. The eighteenth had already communicated to them a rapid movement in advance. Two individuals, Linnæus and Buffon, had especially co-operated in producing this movement; and although endowed otherwise with very different qualities, it is to be remarked, nevertheless, that it was from the same cause that both had failed in their aim. Those phenomena, in effect, those beings, those facts, which the comprehensive genius of Linnæus sought to distinguish and to classify; those facts which the soaring genius of Buffon sought to combine and to explain, were not yet sufficiently known in their intimate nature to supply either their true classification or their real explanation.

The primary merit of M. Cuvier, and it was by this merit that he communicated from the first a new life to the natural sciences, was the distinct perception

* Read before the Academy of Sciences, 29th December, 1834.

that the classification as well as explanation of facts could be founded only on their inmost nature thoroughly understood. In a word, and taking into view only the natural history of animals, that branch of natural history in general which M. Cuvier has most directly elucidated by his labors, it is evident that what had been wanting to Linnæus and to Buffon, whether for the classification of animals or for the proper explanation of their phenomena, was the adequate knowledge of their internal structure or organization; and it is not less evident that the laws of all classification, as of the whole natural philosophy of these beings, could spring only from the laws of that organization itself.

It will presently be seen that it was by the assiduous study of these fruitful laws that M. Cuvier renovated in succession zoology and comparative anatomy; that he renovated them one by means of the other; and that he founded on both the science of fossil animals—a science altogether new, wholly due to his genius, and which has thrown light in its turn on the science of the earth itself. But before we come to these last and astonishing results, the fruits of so many grand conceptions and so many unexpected discoveries, let us first see what he has done in particular for each of the sciences just mentioned, in order that we may afterward be better able to comprehend and embrace in a general view what he has done for all. I commence with zoology.

Linnæus, who of all the naturalists of the eighteenth century had exerted the most general influence on the human mind, particularly in point of method, divided the animal kingdom into six classes: *quadrupeds, birds, reptiles, fishes, insects*, and *worms*. In this Linnæus committed a first general error, for in placing in the same line these six primitive divisions, he assumed that an equal interval separated them one from another; than which nothing could be less exact. On the other hand, almost all these classes, especially the last, at one time separate animals the most nearly related, at another unite those which are most incongruous. In a word, classification, which has no other end but to mark the true relations of beings, in this instance almost everywhere severed those relations; and that instrument of method which only serves the understanding in so far as it conveys just ideas of things, communicated to it, nearly throughout, only false ideas.

This whole classification of Linnæus was, therefore, to be recast, and nearly the entire framework of the science to be reconstructed. Now, to attain this end, it was first necessary to found the classification on organization, for it is organization alone which gives the true relations; in other terms, it was necessary to found zoology on anatomy; it was next necessary to introduce into the method itself views more just and elevated than had been previously applied. It was, in effect, these elevated views as regards method, these profound studies on organization, which shone forth in the first labors of M. Cuvier: potent resources, by means of which he succeeded in effecting successively the reform of all the branches of zoology, one after the other, and in finally renovating in its whole extent that vast and grand science.

I have said that it was chiefly in the class *vermes* of Linnæus that disorder and confusion prevailed. He had thrown into it all animals with white blood—that is to say, more than half the animal kingdom. It was in the first of his memoirs, published in 1795, that M. Cuvier pointed out the great difference of the beings till then confounded under this vague name of white-blooded animals, and that he separated them with precision from one another, first into three great classes: *Mollusks*, which, like the *poulp*, the *cuttle-fish*, the *oyster*, have a heart, a complete vascular system, and respire by means of branchiæ or gills; *insects*, which have, in place of a heart, only a simple dorsal vessel, and respire by tracheæ; and, lastly, *zoophytes*—animals whose structure is so simple as to have gained them this name, signifying animal plants, and which have neither heart, nor vessels, nor distinct organ of respiration. By subsequently forming three other classes—*vermes, crustacea, echinodermata*—all the animals with white

blood are found to be distributed into six classes: *mollusks, crustaceans, insects, worms, echinoderms*, and *zoophytes*.

Everything was new in this distribution; but everything was at the same time so evident that it was generally adopted, and thenceforward the animal kingdom assumed a new face. Moreover, the precision of the characters on which each of these classes was founded, the perfect conformity of the beings which were assembled under each of them, could not but prove convincing to naturalists; and what doubtless appeared to them not less worthy of admiration than these direct and immediate results, was the sudden light which thereby broke on the highest points of the science—the grand ideas on the subordination of the organs and on the office of this subordination in their employment as characters—those great laws of the animal organization thus and so early apprehended: that all animals with white blood which have a heart have also branchiæ or a circumscribed respiratory organ; that all those which have no heart have only a trachea; that wherever the heart and the branchiæ exist, the liver exists; that wherever they are wanting the liver is wanting.*

Assuredly, no one had as yet thrown a glance so comprehensive, so penetrating on the general laws of the organization of animals, and it was easy to foresee that if he should pursue the investigation of those laws with anything like the same continuity, Cuvier, whose first views had imparted to science so brilliant an impulse, would not be long in extending its boundaries in every direction. He has often recalled since, and even in his last works, this first memoir, from which, in truth, date the germs both of the grand renovation which he effected in zoology and of the greater part of his most fundamental ideas in comparative anatomy.

Never, indeed, had the domain of a science been so rapidly augmented. With the exception of Aristotle, whose philosophic genius had neglected no part of the animal kingdom, scarcely had any one studied, at any epoch, more than the vertebrate animals alone, at least in a general and thorough manner. The *animals with white blood*, or, as M. Lamarck has since called them, *the animals without vertebræ*, formed in some sort a new animal kingdom, almost unknown to naturalists, and of which M. Cuvier had at once revealed to them as well the different plans of structure as the particular laws to which each of these plans is subjected. All these animals—so numerous, so varied in their forms, and the knowledge of which has since so greatly extended the basis of general physiology and natural philosophy—were then of scarcely any account to the physiologist and the philosopher; and even long after these great labors of M. Cuvier of which I speak, how many systems have we not seen which, pretending to embrace under one sole point of view the entire animal kingdom, have embraced in reality only the vertebrata? So vast was the new route which he had traced for naturalists, and so difficult was it found to follow him therein, on account of its very vastness.

In this first memoir, then, M. Cuvier had succeeded in finally establishing the true division of animals with white blood. In a second, taking up specially one of their classes, that of the mollusks, he laid the foundations of his great work on those animals—a labor which occupied him for so many years, and which has produced an assemblage of results the most surprising, perhaps, and at least the most essentially new of all modern zoology, as of all modern comparative anatomy.

Till then there had been no example of an anatomy so exact and bearing on so great a number of fine and delicate parts. Daubenton, that model of precision and exactness, had scarcely described with equal detail more than the skeleton and the viscera of quadrupeds; here there was the same attention and a

* By the liver I mean a massive and compact organ, a conglomerate gland; in insects the secretions in effect are accomplished simply by tubes very long and slender, which float in the interior of the body and are fixed only by the tracheæ.

still more eminent degree of sagacity of observation transferred to all the parts of the animal—to its muscles, its vessels, its nerves, its organs of sense. Swammerdam, and Pallas,* who had embraced all the parts of the animal in their anatomizations, had confined these to certain species; in another genus Lyonnet had confined himself to a single one; in the case of Cuvier there was an entire class of animals, and of all animals the class least known, of which almost all the species were described and all the details, even the most delicate and obscure, of their structure were brought to light and developed.

The *mollusks* have all a heart, as already said; some, however, have but a single one, like the oyster and snail; others have two; others again, like the poulp and cuttle-fish, have as many as three distinct hearts. And yet it was with these animals whose organization is so rich, which have a brain, nerves, organs of sense and of secretion, that it had been the custom to confound others, which, like the zoophytes and polypes, for example, have for their whole organization only an almost homogeneous pulp.

The experiments of Trembley have rendered famous the polypus of fresh water, that animal which puts forth buds like a plant, and each part of which, separated from the others, forms a new and complete individual. The whole structure of this singular zoophyte reduces itself to a sac—that is to say, to a mouth and stomach. M. Cuvier has made known another zoophyte,† whose structure presents something still more surprising, for it has not even a mouth; it is nourished by means of ramified suckers, like plants, and its internal cavity serves by turns as a stomach and sort of heart, for vessels enter it which conduct to it the nutritive juices, and other vessels issue from it which convey these juices to the members.

One of the most curious problems of the physiology of *white-blooded animals* which has been resolved by M. Cuvier is that of the nutrition of insects. *Insects*, as has been already said, have, in place of a heart, only a simple dorsal vessel; and, moreover, this dorsal vessel has no branch, no ramification, no particular vessel which either enters or issues from it. This was already known through the celebrated researches of Malpighi, Swammerdam, and Lyonnet. But M. Cuvier goes much further; he examines, one after the other, all the parts of the bodies of insects, and by this detailed examination he shows that no sanguineous vessel, or, what amounts to the same thing, no circulation, exists in these animals. How, then, is their nutrition effected?

M. Cuvier begins by remarking that the final object of the circulation is to conduct the blood to the air. Hence all animals which have a heart have a circumscribed respiratory organ, whether lungs or branchiæ, and the blood returned from the members to the heart is invariably constrained to traverse this organ, in order to be there subjected to the action of the air before returning to the members. But in insects the apparatus of respiration is wholly different. It is no longer a circumscribed organ which receives the air; it is an immense number of elastic vessels, called *tracheæ*, which convey it into all parts of the body, and which thus conduct it even to the nutritive fluid itself, which continually bathes those parts. In a word, while in other animals it is the nutritive fluid which by means of the circulation goes in search of the air, the phenomenon is reversed in insects, and it is the air, on the contrary, which goes to seek the nutritive fluid, and thereby renders all circulation useless.‡

Another discovery of M. Cuvier, not less important, is that of the circulatory apparatus of certain *worms*, such as the earth-worm and leech, which had until then been confounded with those *zoophytes* of a structure incomparably more

* Poli had also preceded him in the anatomy of several molluscs, but of *multivalve* and *bivalve* molluscs only.

† Namely, the blue rhizostome.

‡ We are speaking here only of *perfect insects*. Since the researches of M. Cuvier which I have at present in view, M. Carus has discovered in certain larvæ a sort of circulation, or rather a *movement* of the blood, which movement, however, is not effected in vessels proper.

simple, which live only in the interior of other animals.* By a remarkable singularity the blood of these worms, with a circulatory apparatus,† is red: a new circumstance to show how inexact and vague was the denomination of animals with white blood, given till then, in a general manner, to animals without vertebræ.

By means of these admirable investigations M. Cuvier, it will be seen, had fixed the limits of the class of *mollusks*; he had determined that of the *vermes with red blood*, he had completely separated both from that of the *zoophytes;* finally, he had marked the true place of the zoophytes themselves, thenceforth consigned to the extreme limit of the animal kingdom. But a principle which he had employed in all these researches must needs lead him still further. This principle is that of the subordination of organs or of characters.

Method should not limit itself, in effect, to representing indistinctly the relations of structure; it ought to mark, besides, the particular order of these relations and the relative importance of each, and it is precisely to this end that the principle of the subordination of organs serves. Bernard and Laurent de Jussieu had already applied this principle, as fruitful as it is infallible, to botany, but the zoologists had not yet ventured to make the application of it to their own science, determined, no doubt, by the great number and complication of the organs which constitute the animal body, and which, for the most part, are wanting in vegetables.

The principle of subordination of organs could only be introduced into zoology when preceded by anatomy. The first step to be taken was to know the organs; the determination of their relative importance could be only the second. These two steps accomplished, there remained only to found the characters on the organs, and to subordinate these characters one to the other, as the organs are subordinated among themselves. Such was properly the object of the *Animal Kingdom distributed according to its organization, (Règne Animal, &c.,)* that great work in which the new zoological doctrine of the illustrious author is displayed as at length reproduced in all its entireness and co-ordinated in all its parts.

Dating from this work the art of methods has assumed a new face. Linnæus, as is well known, had seen in this art only a means of distinguishing species. M. Cuvier was the first who undertook to make method the very instrument of the generalization of facts. Method, viewed in itself, is for him only the subordination of propositions, of truths, of facts, one to another, according to the order of their generality. Applied to the animal world, it is the subordination of groups among themselves, according to the relative importance of the organs which constitute the distinctive characters of those groups. Now, the most important organs are also those which involve the most general resemblances. Whence it follows that in founding the inferior groups on the subordinate organs, and the superior groups on the dominating organs, the superior groups will always necessarily comprise the inferior, or, in other terms, it will always be practicable to pass from one to the other by progressive propositions, becoming more and more general in proportion as we ascend from the inferior groups towards the superior.

Method, therefore, properly considered, is but the generalized expression of science; it is science itself, but science reduced to its most simple expressions; it is still more: this linking together of facts according to their analogies, this linking together of analogies according to their degree of comprehensiveness, is not limited to the representation of known relations; it brings to light a multitude of new relations, contained one in another; it disengages them from one another; it thus gives new forces to the understanding for perceiving and discovering; it creates for the mind new processes of logic.

* Namely the intestinal worms, that class of zoophytes which, for the most part, can only live and propagate in the interior of the bodies of other animals.

† *Worms with red blood* of Cuvier: *annélides* of Lamarck.

Hitherto M. Cuvier had seen, in each of these grand classes of invertebrate animals, *mollusks*, *insects* and *zoophytes*, only a group like each of the four classes of vertebrate animals, *quadrupeds*, *birds*, *reptiles* and *fishes*. It was because he had as yet considered only the organs of circulation.

In considering the nervous system, which is a much more important organ, he saw that each of the three great classes of animals without vertebræ corresponded or was equivalent not to such or such a class of *vertebrate* animals taken separately, but to all these vertebrate animals taken together. A first form of the nervous system unites all these vertebrate animals in a single group; a second form unites all the mollusks; a third unites the insects to the worms with red blood, and both to the crustacea, constituting the group of articulata; a fourth form, finally, unites all the zoophytes. There are thus four plans, four types in the animal kingdom, four *embranchements*, as M. Cuvier calls them; or, in plainer terms, and divested of everything vague, there are four general forms of the nervous system in animals.

In the sciences of observation and experiment the supreme art of genius is to transform questions from simple questions of reasoning into questions of fact. For more than a century the question had been debated whether, in animals, there was but one plan of organization, or whether there were several. This question, couched till then in terms so vague, is transformed by M. Cuvier into this other question, positive and to the point, namely, how many distinct forms are there of the nervous system in animals? Now, as I have just said, there are four—one for the *vertebrata*, one for the *mollusca*, one for the *articulata*, one for the *zoophyta;* these four plans or types comprising the whole animal kingdom.

Such is the light thrown upon the animal kingdom by the great work under consideration that, guided by this, the mind is enabled precisely to apprehend the different orders of relation which connect animals with one another; the relations of conformity *(d'ensemble)* which constitute the unity, the character of the kingdom; the relations more or less general which constitute the unity of the *embranchements*, of the classes; the more particular relations which constitute the unity of the orders, of the genera.

Nevertheless, this work of so vast a scope, of such immense detail, was not yet what M. Cuvier would have wished. It is the property of genius always to see something beyond and better than all that it has done. And, indeed, though all the species had been reviewed in this great work, the greater part of them had been scarcely more than indicated; it was, therefore, only an abridged, not a complete system of animals. Now, the idea of a complete system of animals, a system in which all the species should be not only indicated, distinguished, classified, but represented and described in their whole structure, was one of those with which M. Cuvier was most constantly occupied. Hence, scarcely was this great treatise on the animal kingdom terminated, when another was already commenced, and on a plan not less vast. I mean the "Natural History of Fishes," *(Histoire naturelle des poissons,)* the first volume of which appeared in 1828.

After having effected, in the earlier of these two works, the complete reform of the system of animals, what he had wished in the second was to show, by a detailed and thorough exposition of all the known species of a class, what could be done for all other species and all other classes. With this view he had chosen the class of *fishes* as being, among all those of the vertebrata, the most numerous, the least known, and that most enriched by the recent discoveries of travellers. The latest authors of note in ichthyology, Bloch and Lacépède, were scarcely acquainted with so many species of fish as 1,400; in the work of M. Cuvier the number of species would have amounted to more than 5,000; the entire work would have included not less than 20 volumes, all the materials were placed in order, and the nine volumes which made their appearance in less than six years fully attest the wonderful rapidity with which it was intended that this vast undertaking should proceed

Pressed by want of time I must deny myself all details on this work, so astonishing for its extent, and yet still more astonishing for that profound art in the formation of genera and families, of which the author seems to have delighted to unveil the most hidden secrets, and for that science of characters which no one ever possessed in an equal degree; results of experience and fruits of a genius arrived at its full maturity.*

Such is the assemblage of great labors by which M. Cuvier has renovated zoology; but a reform still more important, and of which that is in reality but the consequence, is what he had already effected, or was at the same time effecting in *comparative anatomy.* It is impossible to speak of the progress which this science owed to the researches of M. Cuvier without profound respect and even grateful acknowledgment; he himself regarded this branch of investigation, and with justice, as the regulator of all those which relate to organized beings, and death surprised him still meditating that great work which he had consecrated to it, and in which, collecting anew all its forces, his vast genius would have undoubtedly appeared in all its grandeur. But though this work remained unaccomplished, its principal elements subsist, as they are scattered in various memoirs, especially in his *Leçons d'anatomie comparée* and his *Recherches sur les ossements fossiles*, immortal labors which have communicated to comparative anatomy such an impulsion that, after having been so long the most neglected of the branches of natural history, it has suddenly outstripped and taken the lead of all of them.

The history of comparative anatomy counts three epochs clearly marked—the epoch of Aristotle, that of Claude Perrault, and that of Cuvier. Every one knows with how much genius the foundations of the science were laid by Aristotle among the ancients. But what is not as well known, though not less worthy of being so, is the force of intellect with which Claude Perrault, at the middle of the seventeenth century, undertook the reconstruction of the entire science from its very base—that is to say, from the consideration of particular facts. His descriptions are the first assured step taken by comparative anatomy in modern times. Daubenton advanced it still another, for he rendered those descriptions comparable. Vicq-d'Azyr went yet further. Rich through the labors of Daubenton, of Haller, of Hunter, of Monro, of Camper, of Pallas, Vicq-d'Azyr embraced comparative anatomy in its completeness; he brought to it that penetrating genius which sees in science the end to be attained, and that spirit of sequence which attains it; and by no one more than by him was that great reform promoted which M. Cuvier finally achieved for the science in question.

It was certainly fortunate for this science to have passed immediately from the hands of one of these two eminent men into the hands of the other. Vicq-d'Azyr had thrown on it the glance of the physiologist; M. Cuvier threw on it more particularly that of the zoologist, and we may concede that it had an equal need of being considered under both these points of view. It may well be thought that its reform would not have been so complete and its influence so general except that, having been by turns studied and adapted with a view both to zoology and physiology, it has become alike for both the guide and the luminary.

However this may be, comparative anatomy was still but a collection of particular facts touching the structure of animals, when M. Cuvier transformed it into the science of the general laws of the animal organization. After having transformed, as we have seen, the zoological method from being a simple nomenclature into an instrument of generalization, he now proceeded to dispose the facts in comparative anatomy in such an order that, from their simple collocation, have proceeded so many admirable and progressively ascending laws; as, for example, that each kind of organ has its fixed and determined modifications; that a con-

* See, respecting this work, the developments which I present in my *Histoire des Travaux de M. Cuvier.*

stant relation connects all modifications of the organism with one another; that certain organs exert on the collective animal economy a more marked and decisive influence, whence the law of their *subordination;* that certain facts of organization necessarily involve the presence of each other, while there are such, on the contrary, as are incompatible and exclusive, one of the other, whence the law of their *correlation* or *coexistence;* besides so many other laws, so many other general relations, which have, in the end, created and developed the philosophic part of the science.

Among so many discoveries, so many particular facts with which he has enriched that science, I must necessarily confine myself to a citation of the most prominent, and still the catalogue of even these will be far from complete. The researches of Hunter and of Tenon had already afforded valuable contributions to the theory of the development of the teeth; it was Cuvier who carried this theory to a perfection beyond which there can be little to desire. Those little bones which we call teeth appear at first glance to be very simple, and scarcely to merit the attention of the observer. These little bodies, however, are very complex; they possess secretory organs, as their *germ*, their *proper membrane;* secreted substances, such as their *enamel*, their *ivory;* and each of these substances appears in its turn, each at a fixed epoch. They spring up, are developed, push forth their roots, die, fall, and are replaced by others with admirable order and regularity. Nor is it less admirable, though under another point of view, that all the circumstances of their organization and development are to-day rigorously demonstrated. It was chiefly through a study of the teeth of the elephant, where everything is seen on a large scale, that M. Cuvier succeeded in establishing the precise epoch at which each part of the tooth is formed, and by what mechanism it is formed; how each of these parts, having performed its function of productive organ, disappears; how the entire tooth disappears in its turn to give place to another, which will also have its development, both in the whole and in detail, its point of complete organization, and its decay and its fall.

Perrault, Hérissant, Vicq-d'Azyr, had, before Cuvier, distinguished some points in the structure of the vocal organs of birds; he has made that structure known in a general manner and by detailed comparisons. It was he also who first placed in a clear light the singular arrangement of the organ of hearing, and still more singular arrangement of the nasal *fossæ* in the cetaceous tribes.

Every one knows the marvellous metamorphosis experienced by the frog in passing from the state of fœtus or tadpole to the adult state. It is known that after having respired, in the first case, by gills, like the fishes, it respires, in the second, by lungs, like the terrestrial animals. M. Cuvier has taught us the structure of the organs of respiration and of circulation in a species of reptiles, which presents something still more curious. The frog is by turns a fish in its first stage, and a reptile in its second. These new reptiles, still more singular, such as the *proteus*, the *axolotl*, the *siren*, are all their life reptiles and fish; have all the time both *branchiæ* or gills and lungs, and can hence breathe alternately in the air and in water.

M. Cuvier again was the first to give a connected comparison of the brain in the four classes of vertebrate animals; the first to point out the relations of the development of that organ with the development of intelligence, a branch of comparative anatomy which has since become so fruitful and extensive; the first, in fine, to deduce in a rigorous manner from the respective quantity of respiration of these animals, not only the degree of their natural heat, but that of all their other faculties, their force of movement, their subtility of perception, their rapidity of digestion.

But the most novel and brilliant application which he has made of comparative anatomy, is that which relates to *fossil bones*. Every one now knows that the globe which we inhabit presents, almost everywhere, irrefutable traces of stupendous revolutions. The productions of the actual creation, of living nature,

everywhere cover the remains of an earlier creation, of a ruined nature. On the one hand immense masses of shells and of other marine bodies are found at great distances from any sea, at heights to which no sea could now attain, and from thence have been derived the first facts in support of all those traditions of deluges preserved among so many tribes of mankind. On the other hand, the large bones discovered from time to time in the bowels of the earth, in the caverns of the mountains, have given rise to those other popular traditions, not less diffused and not less ancient, of races of giants which have peopled the world in its first ages.

The traces of the revolutions of our globe have, therefore, at all times impressed the minds of men, but they long impressed them in vain, and only with a fruitless astonishment. For a long time, indeed, ignorance was carried to such a point that an opinion very nearly universal, and I speak not here of popular opinion, but of the opinion of savants and philosophers, regarded the stones charged with the impressions of animals or plants and the shells found in the earth as *sports of nature.* "It was necessary," says Fontenelle, "that a common potter, who knew neither Latin nor Greek, should dare, about the end of the sixteenth century, to say in Paris, and in the face of all the doctors, that the fossil shells were real shells, deposited heretofore by the sea in the places where they were then found; that animals had impressed on the figure-bearing stones all their different figures, and that he should boldly defy the whole school of Aristotle to contest his proofs."

This potter was Bernard Palissy, renowned for having made barely a first step in a route traversed since then by so many great men, and which has conducted them to such astonishing discoveries. In truth, the ideas of Palissy could scarcely be expected to attract notice at the epoch when they appeared, and it was not till about a century later—that is to say, toward the close of the seventeenth century—that they began to revive, and, again to recall an expression of Fontenelle's, "to thrive in the world as they deserved to do." But from that time such was the activity put forth, both in collecting the remains of organized bodies buried beneath the surface of the earth and in studying the strata which contain them, and under this twofold relation so rapidly were significant facts multiplied, that some bold and perspicacious minds were not afraid even then to combine them in generalizations and attempt to ascend to their causes. It was, in effect, at the close of the seventeenth century, and during the first half of the eighteenth, that the celebrated systems of Burnet, Leibnitz, Woodward, Whiston, and Buffon made their appearance—all of them premature and more or less erroneous, no doubt, but productive of this advantage, that they accustomed the human intellect to contemplate these astounding phenomena in a philosophic spirit, and not to shrink from measuring itself against them.

Another advantage, of even greater moment, was, that all these systems, by exciting a strong interest, presently drew together from all parts observations at once more numerous, precise and complete; the first effect of which was to overturn all that was imaginary and absurd in those systems; and the second, to found on their ruins the true theory, the positive history of the earth.

The eighteenth century, which advanced so rapidly in so many directions, perhaps witnessed nothing more rapid than the progress of the science of which we are speaking. The same century which in its first moiety had seen all the systems just spoken of, structures as brilliant as frail, either rise or fall, this century saw, in its second, the first foundations of the enduring monument which was to succeed them, cast by the hands of a Pallas, a Deluc, a de Saussure, a Werner, a Blumenbach, a Camper, and others who so ably seconded them.

Among these advances it is proper that I should here especially recall those which relate to the fossil remains of organized bodies. It was these remains, in effect, subsisting witnesses as they are of so many revolutions, so many violent subversions sustained by the globe, which had given rise to the first hypothesis

of the *fantastic* geology; and it was again these remains which, in the hands of M. Cuvier, furnished the results the most evident and the laws best ascertained of the *positive* geology. The researches of M. Cuvier were principally directed to the fossil bones of quadrupeds—a part of the animal kingdom till then little studied under this new point of view, but the study of which was calculated to lead to consequences much more precise and decisive than that of any other class.

I have already mentioned the large fossil bones discovered at different epochs, and the absurd ideas of giants, which were renewed at each discovery which was made of them. Daubenton was the first to overthrow all these ideas; it was he who first applied comparative anatomy to the determination of the remains in question; but, as he himself avows, this science was as yet far from being sufficiently advanced to furnish, in all cases and with sufficient certainty, the species or genus of animal to which an unknown and isolated bone might appertain, and yet such was the problem to be solved. The memoir in which Daubenton attempted for the first time the solution of this important problem was of the date of 1762.

In 1769 Pallas published his first memoir on the *fossil bones of Siberia.* It was not without surprise that the demonstration was here seen of the fact that the elephant, the rhinoceros, the hippopotamus—animals which at present live only under the torrid zone—had heretofore inhabited the most northern portions of our continents. The second memoir of Pallas could not but excite still more wonder, for he there reports the fact, which could scarcely seem credible at that time, that a rhinoceros had been found entire in the frozen earth with its skin and flesh—a fact since renewed, as is known to all, in the elephant discovered in 1806 on the shores of the Glacial sea, and so well preserved that dogs and bears devoured its flesh and disputed its remains with one another.

The impulse once communicated by Pallas, the relics of animals of the south were soon found, not only in the countries of the north, but in all the regions of the old as well as new world. Buffon, from these facts, hastened to deduce his hypothesis of the gradual refrigeration of the polar regions and of the successive migration of animals from the north to the south. But the last fact observed by Pallas, and which has just been cited, had already overthrown this assumption. That fact effectually demonstrated, in the most formal manner, that the refrigeration of the globe, far from having been gradual, had, on the contrary, necessarily been sudden, instantaneous, without any gradation; it demonstrated that the same instant which destroyed the animals in question had rendered the country of their habitat glacial; for had they not been frozen as soon as killed it is evident that they could not have descended to us with their flesh and skin and every part in perfect preservation. The hypothesis of gradual refrigeration being thus untenable, Pallas substituted that of an irruption of water coming from the southeast—an irruption which, he maintained, would have transported into the north the animals of India; but this second hypothesis was not more happy than the first, for the fossil animals are very different from those of India, and indeed from all animals now living—a final fact more extraordinary still than all which preceded it, and which it was reserved for M. Cuvier to place in the clearest light.

The fact of an ancient creation of animals entirely distinct from the existing creation, and long since entirely lost, is the fundamental fact on which rest the most evident proofs of the revolutions of the globe. It cannot, therefore, be without interest to observe how the idea of this fact, assuredly the most extraordinary which scientific research has been enabled to discover and to prove, had its first rise, its subsequent development, and final confirmation.

We have seen how, toward the end of the sixteenth century, Bernard Palissy had ventured, first among the moderns, to maintain that the bones, the impressions, the fossil shells, so long regarded as casual freaks of nature, were the

remains of real creatures, the veritable spoils of organized bodies. In 1670 Augustine Scilla renewed the opinion of Palissy and sustained it with vigor. Shortly after, in 1683, Leibnitz lent to it the authority of his name and genius. Finally, from the first half of the eighteenth century, Buffon reproduced it with still more splendor, and directly made it popular.

But are these organized beings, of which innumerable relics are scattered everywhere, the analogues of those which are now living, whether in the places where these relics are found or in others? or have, indeed, their species, their genera, perished? It is here that the difficulty lies, and we may well believe that this difficulty would never have been resolved, at least with complete certainty, as long as the inquiry had been restricted, for example, to the study of fossil shells or of fishes. It would have availed little, in effect, to find new shells, new fishes; we should have been always at liberty to suppose that their species were still living, whether in distant seas or at inaccessible depths. Not so, however, as regards quadrupeds. The number of these is greatly more limited, especially for the larger species, we may count on attaining a knowledge of all of them—how vastly more easy then to satisfy ourselves whether certain unknown bones belong to one of these species still living, or whether they proceed from such as are lost.

This it is which gives to the study of fossil quadrupeds a peculiar importance and to the deductions which may be drawn from it a force which deductions derived from a study of most of the other classes could not possess. Buffon seems to have felt this. It was chiefly on the great fossil bones of Siberia and Canada that he sought to sustain the conjecture (for, in view of the state of comparative anatomy at the time when he wrote, it could be only a conjecture) of certain lost species. Besides, even this conjecture was so imperfectly established in his own mind, at least in relation to quadrupeds, that after having regarded, in his *Théorie de la Terre*, all the animals to which these extraordinary bones had belonged as lost, he afterwards declared, in his *Époques de la Nature*, that he no longer recognized more than a single lost species—that which has been called the *mastodon*—and that all the other bones in question are merely those of the elephant and the hippopotamus.

Camper went much further, as might have been expected, for comparative anatomy had not failed to advance by long strides since the days of Buffon. In 1787, in a memoir addressed to Pallas, Camper boldly enunciates the opinion that certain species have been destroyed by the catastrophes of the globe, and, moreover, sustains it by the first really positive facts, though still very incomplete, which had yet been advanced in its support. Thus, in proportion to the determination of fossil bones has been the progress of the idea of lost animals, and it has always been by the light of comparative anatomy that this progress was accomplished. It was, in effect, this light of comparative anatomy which had been wanting to so many laborious researches of so many naturalists. But it is easy to see that towards the epoch of which I speak, towards the close, namely, of the eighteenth century, everything was prepared for the long-sought solution; that the moment was at hand for some revelation, some complete and definitive result respecting these strange and marvellous phenomena.

The 1st Pluviose, an IV, (February, 1796,) being the day of the first public session held by the National Institute, M. Cuvier read before the assembled body his memoir on the *fossil species of the elephant* compared with the *living species*. It was in this memoir that he announced, for the first time, his views on extinct animals. Thus, on the same day when the Institute opened the first of its public sessions, was opened also the career of the greatest discoveries which natural history has made in our age: a singular coincidence, which the history of the sciences should not fail to mark and commemorate.

M. Cuvier had now initiated that brilliant series of researches and labors which occupied him so many years, and which, during the whole time, called

forth renewed surprise and admiration on the part of his contemporaries. In this first memoir he does not confine himself to demonstrating that the fossil elephant is a distinct species from the existing species—that it is a species extinct and lost; he expressly declares that the greatest step which could be made towards the perfection of the theory of the earth, would be to prove that none of those animals whose remains are found dispersed over nearly all points of the globe, any longer exist. He adds that what he then established in regard to the *elephant* he would soon establish in a not less incontestable manner in regard to the fossil *rhinoceros*, *bear*, and *deer*, all of them species equally distinct from living species, all of them equally lost. Finally he concludes with the following remarkable words, in which he seemed to announce all that he has since discovered: "If it be asked why we find so many remains of unknown animals, while we find none of which it can be said that they belong to species that we know, it will be seen how probable it is that they have all pertained to the creatures of a world anterior to our own; to creatures destroyed by some catastrophe of the globe; to creatures whose place has been filled by those which exist to-day."

Thus the idea of an entire creation of animals anterior to the actual creation, the idea of an entire creation destroyed and lost had at last been fully conceived; and had found an utterance which proved to be a final solution of the doubts which, for a century, had so strongly occupied the human mind.

But, in order to transform into a positive result views thus vast and elevated, it was necessary to assemble from all quarters the remains of the lost animals, to pass them in review, to study them under this new aspect; it was necessary to compare them all, one after the other, with the remains of living animals; and, first of all, it was necessary to create and determine the art itself by which this comparison was to be made.

Now, for a right conception of all the difficulties of this new method, this new art, it is sufficient to remark that the *débris* of the animals in question, the *fossil bones*, are almost always isolated and dispersed; that often the bones of several species, and those the most diverse, are mingled in confusion; that almost always these bones are mutilated, broken, reduced to fragments. It was requisite, therefore, to refer each bone to the species to which it pertained; to reconstruct, if possible, the complete skeleton of each species, without omiting any of the pieces which were its own, without intercalating any which were foreign to it. Let us now represent to ourselves this confused intermingling of mutilated and imperfect relics assembled together by M. Cuvier; let us conceive each bone, each portion of a bone, taking its place under his skilful hand, each uniting itself to the bone or portion of bone to which it had pertained; let us observe all these species of animals, destroyed for so many ages, thus rising before us in their various forms, with each character, each attribute restored, and we shall scarcely realize that we are witnessing a simple anatomical operation, but rather a sort of resurrection; nor will it abate anything of the prodigy that it is a resurrection effected at the voice of science and of genius.

I say *at the voice of science*. The method employed by M. Cuvier for this wonderful reconstruction is, in effect, but the application of the general rules of comparative anatomy to the determination of *fossil bones*. And these rules themselves are a not less grand, less admirable discovery than the surprising results to which they have led.

It has been seen above how a rational principle, that of the *subordination of organs*, everywhere applied, everywhere reproduced in establishing the groups of the method, had changed the face of the classification of the animal kingdom. The principle which presided at the reconstruction of lost species is that of the *correlation of forms*, a principle by means of which each part of an animal may be given by each other part, and the whole animal by a single part. In a mechanism as complex, and yet as essentially a unit as that which constitutes

the animal frame, it is evident that all the parts must necessarily be constructed one with reference to the others, so as to correspond, to adapt themselves to one another, to form, in a word, by their assemblage, one being, one unique system. A single one of these parts, therefore, cannot change its form without necessitating a change in form of all the others. Hence from the form of one part may be deduced the form of all the other parts.

Suppose a *carnivorous* animal; it will necessarily have the organs of sense and of movement; the claws, teeth, stomach, intestines, adapted for scenting, seizing, tearing, digesting its animal prey, and all these conditions will be rigorously linked with one another; for, if one be wanting, the others would be without effect, without result; the creature could not subsist. Suppose, on the other hand, an herbivorous animal; all this assemblage of conditions will have changed. The teeth, the feet, the stomach, the intestines, the organs of movement and of sense, will all have assumed new forms, and these new forms will always be proportioned and related one to the others. From the form of a single one of these parts, therefore, from that of the teeth alone, for example, we may infer, and infer with certainty, the form of the feet, that of the jaws, that of the stomach, that of the intestines.

All the parts, all the organs, are deducible, then, one from the other; and such is the rigor, such the infallibility of this deduction, that M. Cuvier has been often known to recognize an animal by a single bone, nay by the facet of a bone; that he has been known to determine unknown genera and species from a few broken bones, and this from such or such a bone taken at random, reconstructing in this way the entire animal from a single one of its parts, and causing it to reappear, as at will, from each of them; results which cannot be recalled without recalling in effect all that admiration, mingled with surprise, which they at first inspired, and which is not yet exhausted.

That precise and rigorous method of distinguishing bones confounded together—of referring each bone to its species; of reconstructing the entire animal from some of its parts—that method once conceived, it was no longer by isolated species but by groups and masses that these extinct populations, antique monuments of the revolutions of the globe, reappeared. An idea might then be formed not only of their extraordinary appearance, but of the prodigious multitude of their species. It was seen that they comprised creatures of all classes, quadrupeds, birds, reptiles, fishes, down to crustacea, mollusks, and zoophytes. Nor, though I speak here only of animals, does the study of fossil vegetables furnish consequences less curious than those drawn from the animal kingdom. All these organized beings, all these first occupants of the globe, are distinguished by their proper characters, and often by characters the most singular and grotesque.

Among the quadrupeds, for example, we first observe the *palæotherium*, the *anoplotherium*, those strange specimens of pachydermata, discovered by M. Cuvier in the environs of Paris, and of which none bearing this peculiar character has descended to our times. Afterwards comes the *mammoth*, that elephant of Siberia, covered with long hairs and a thick wool; the *mastodon*, an animal almost as large as the mammoth, and whose teeth, armed with points, long caused it to be regarded as a carnivorous elephant, together with those enormous sloths, the *megatherium*, the *megalonyx*, animals of which the existing species do not exceed the size of a dog, while some of those which are lost equalled the largest rhinoceros. Still more extraordinary were the *reptiles* of those first ages of the world,* whether from their gigantic proportions, for there were *lizards* as large as whales, or from the singularity of their structure, for some had the aspect of the *cetacea* or marine mammifers, and others the neck and beak of birds, and even a kind of wing.

* Such as the *megalosaurus*, which was more than 60 feet in length; the *ichthyosaurus* and the *plesiosaurus*, whose members are called those of the *cetacea*; the *pterodactyls*, which have a very long projection from the anterior extremity, bearing a membrane or sort of wing.

And what is still more surprising is that all these animals did not live at one and the same epoch; that there were several generations, several populations, so to speak, successively created and destroyed. Of these M. Cuvier has counted as many as three distinctly marked. The first comprised the mollusks, the fishes, the reptiles, all those monstrous reptiles just spoken of; among them were already found some marine mammifers, but no terrestrial mammifer, or scarcely any, then existed. The second epoch was chiefly characterized by those strange species of pachydermata of the environs of Paris, above mentioned, and it was now only that the terrestrial mammifers began to predominate. The third was the epoch of the *mammoth*, the *mastodon*, the *rhinoceros*, the *hippopotamus*, the *gigantic sloths*. A remarkable fact is that among all these animals there is scarcely one of the *quadrumana;* scarcely one of the ape tribe.* And still more remarkable, there was no man; the human race therefore was neither cotemporaneous with any of these lost species nor with the catastrophes which destroyed them †

Thus, then, after the age of reptiles, after that of the first terrestrial mammifers, after that of the mammoths and mastodons, arrived a fourth epoch, a fourth succession of created beings, that which constitutes the actual population, that which may be called the *age of man*, for from this age only dates the human species. The creation of the animal kingdom, therefore, has undergone several interruptions, several successive destructions; and what is not less wonderful, though altogether certain, is, that there was an epoch, the first of all, when no organized being, no animal, no vegetable existed on the globe.

All these extraordinary facts are demonstrated by the relations of the remains of organized beings to the strata which form the crust of the globe. Thus there was a first epoch when these beings did not exist, for the primitive or primordial formations contain none of their remains; the reptiles prevailed in the following epoch, for their remains abound in the formations which succeed the primitive; the surface of the earth has been several times covered by the seas, and again left dry, for the remains of marine animals cover turn by turn the remains of terrestrial animals and are alternately covered by them.

Thus has science, guided by genius, been enabled to ascend to the most remote epochs of the history of the earth; to compute and determine those epochs; to mark both the first moment when organized beings appeared on the globe, and all the variations, modifications, and revolutions they have experienced. It were unjust, doubless, to convey the impression that all the proofs of this great history have been collected by M. Cuvier; but even where others after him have made discoveries in the same field, some portion of glory must redound to him by whose footsteps they have been guided. It may be said, indeed, that the more valuable those discoveries, the more important all those which shall be made in the future, the more will his renown be enhanced, even as the name of Columbus has been exalted in proportion as the navigators who have come after him have rendered better known the whole extent of his conquest.

This unknown world opened to naturalists is undoubtedly the most brilliant discovery of M. Cuvier. Yet I do not hesitate to place beside it that other discovery, in my eyes not less important, of the true method in natural history.

The need of methods to our understanding arises equally from the need it has of *distinguishing* in order to know, and the need it has of *generalizing* what it knows in order to be able to embrace and clearly to conceive the greatest possi-

* Since the above was written some remains of apes have been found among fossil bones. See *Hist. des travaux de M. Cuvier.*

† More recent investigations have led to a different conclusion; from these it seems to have been established that the appearance of man upon earth must be carried back much further than has been generally supposed; that he witnessed more than one of the catastrophes alluded to, and was obliged to dispute his mundane inheritance with several of the gigantic or ferocious animals of the "third epoch." See Smithsonian Report for 1867, "Man as a cotemporary of the mammoth, &c."—Tr.

ble number of facts and of ideas. All method has, therefore, a double object, namely, the *distinction* and the *generalization* of facts. Now, till M. Cuvier's method had been limited to separating and distinguishing; it was he who made of it, as I have already said, an instrument of generalization, by which he has rendered a lasting service not only to natural history, but, I venture to assert, to all the sciences.

For method, understanding thereby the true method, is essentially one. Its object everywhere is to raise itself to the most general relations, to the most simple expression of things, and in such sort that all these relations shall spring one from the other, and all from particular facts which are the origin and source of them. It is this which Bacon meant when he said that all our sciences are but generalized facts, a phrase which admirably denotes the process followed by M. Cuvier.

This generalization of facts was, in effect, the potent instrument by which he created the science of fossil remains; by which he renewed, in every part, geology and comparative anatomy; by which he was enabled, in every order of facts, to pursue them to their principle, and their ultimate principle, carrying zoological classification to its rational principle, the *subordination of organs;* founding the reconstruction of extinct animals on the principle of the *correlation of forms;* demonstrating the necessity of certain intervals, certain interruptions in the scale of beings, by the very impossibility of certain coexistencies, of certain combinations of organs. It is in this habit of his intellect of ascending in everything to a principle unassailable and demonstrated that we must seek the secret of that inimitable clearness which he sheds over all the subjects of which he treats; for clearness results in all cases from the ordering of the thoughts and the unbroken chain of their inter-dependence. It is in this habit, moreover, that we find the reason why his opinions, in every kind, are so fixed, so final; it is because he never contents himself with isolated and fortuitous relations, but always ascends to those which are necessary, and of these allows none to escape him.

In M. Cuvier two things equally strike us: the extreme precocity of his views, for it was by his first memoir on the class *vermes* of Linnæus that he reformed not only that class, but, through it, the whole of zoology; it was by his first course of comparative anatomy that he recast the entire science and re-established it on a new basis; it was by his first memoir on fossil elephants that he laid the foundation of a science wholly new, the science of extinct animals; and again, that spirit of sequence, of perseverance, of undiverted constancy, by which he developed and fertilized his views, consecrating an entire life to establish, to demonstrate them, to mature them by experiment, to transform them finally from simple views, fruits of a bold conception, of a sudden inspiration, into truths of fact and observation.

If we follow this celebrated man in the different paths he has traced, we find throughout those dominant qualities of his genius, order, comprehensiveness, elevation of thought, clearness, precision, force of expression. We find all these qualities united to a style still more animated, varied, and forcible in those *Eloges Historiques* which long formed so large a part of the charm and *éclat* of the public meetings of the academy. On these memoirs praise has been already lavishly bestowed, nor would it be easy too highly to extol the spirit and animation which diffuse through them so much movement and life; the art of so piquantly recounting an anecdote or painting a characteristic; the vigor of conception which binds all the parts of the discourse into a whole so compactly put together that it might seem to have been created at a single stroke; the singular aptitude, in fine, to rise to the most varied and comprehensive considerations and to depict so many different personages in a manner equally just and striking. If examined with somewhat closer attention we remark, and with perhaps even greater pleasure, the same sagacity of observation, the same analogical subtlety,

the same art of comparing and subordinating, of ascending to the ultimate generalization of facts, here transferred to another field; and, in addition to all this, those luminous and penetrating touches which suddenly arrest the attention of the reader and transport him to the level of an elevated order of ideas.

M. Cuvier seems, in effect, to have been destined to give a new character to whatever passed through his hands. Into his instructions upon natural history he introduced those philosophic and general views which had scarcely before penetrated to the schools. In his eloquent lectures the history of the sciences became the history of the human mind itself, for in going back to the causes of their progress and their errors he was always careful to point out that those causes were to be found in the right or the wrong processes which the human mind had pursued. It was here that, to use one of his own happy expressions, he *submitted the human mind to experiment*, showing, by the whole testimony of the history of the sciences, that the most ingenious hypotheses, the most brilliant systems, do but pass and disappear, and that facts alone remain; opposing everywhere to the methods of speculation, which have never produced any durable result, the methods of observation and experiment, to which we owe all the discoveries and all the real knowledge which constitute the actual heritage of mankind.

Ah! in what mouth could these great results, drawn from the history of science—that *experimental theory* of the human mind, if I may so speak—have more authority than in his? Who has shown himself more constantly attached to observation, to experiment, to the rigorous study of facts, while at the same time enriching his era with truths the most novel and sublime?

Since men have observed with precision, and have pursued experiment in a consecutive manner, a space of some two centuries, they ought, it would seem, to have renounced the mania of seeking to *divine*, instead of *observing;* for, in the first place, it must prove wearisome in the long run to be always divining unskilfully; and, in the next place, it should by this time have been recognized that what we *imagine* is always below what really *exists*, and that, in a word, and to consider only the brilliant side of our theories, the marvellous of the imagination is always very far from approaching the marvellous of nature.

The delivery of M. Cuvier was in general grave, and even somewhat slow, especially towards the opening of his lectures; but soon his utterance became animated by the movement of his thoughts, and then this movement, communicated by the thought to the expression, the penetrating voice, the inspiration of his genius reflected in his eyes and on his features, all conspired to produce upon his audience the most vivid and profound impression. One felt exalted even less by those grand and unexpected ideas which shone throughout than by a certain force of conception and of thought which seemed by turns to arouse and penetrate the mind of the hearer. Into the career of the professor he carried the same character of invention as into the career of research and discovery. After having remodelled the school of comparative anatomy at the *Jardin des Plantes*, we have seen him convert a simple chair of natural history at the College of France into a true chair of the philosophy of the sciences: two creations which well portray his genius, and which in the eyes of posterity must reflect honor on our age.

M. Cuvier has left memoirs of his life, designed, as he himself writes, for him who should have to pronounce his eulogy before this Academy. The care which he has thus taken in favor of my auditory makes it imperative on me to add some details taken from those memoirs: "I have composed (he says in beginning) so many *éloges historiques* that there is no presumption in thinking that some one will compose mine, and knowing by experience what it costs the authors of this sort of writings to become informed respecting the life of those of whom they have to speak, I wish to spare that trouble to him who shall occupy himself with my own. Linnæus, Tenon, and others, perhaps, have not judged this

attention to be beneath them, and they have therein rendered a service to the history of the sciences. These (he continues) are respectable examples, and which I may oppose to those who shall tax me on this point with a trifling vanity."

He did not foresee that the details of his life were destined to become so popular that he who should have the honor of pronouncing his eulogy would scarcely dare to reproduce them.

George Cuvier* was born August 23, 1769, at Montbéliard, a city then belonging to the duchy of Wurtemberg, but which has since been reunited to France. His family was originally from a village of the Jura which still bears the name of Cuvier. At the era of the Reformation it had established itself in the little principality of Montbéliard, where some of its members have filled distinguished places. The grandfather of M. Cuvier was of one of the poorer branches; he was town clerk. Of two sons whom he had, the second entered a Swiss regiment in the service of France, and having become, through good conduct and bravery, an officer and chevalier of the order of merit, married, at the age of fifty years, a woman still quite young, and whose memory should be dear to posterity, for she was the mother of Cuvier, and, moreover, his first preceptor.

A woman of superior mind, a mother full of tenderness, the instruction of her son soon became her whole occupation. Although she did not know Latin, she made him repeat his lessons; execute his drawings under her eyes; read to her many books of history and literature; and it was thus that she developed, that she nourished in her young pupil that passion for reading, and that curiosity about all things, which, as M. Cuvier himself says in the memoirs intrusted to me, had formed the mainspring of his life.

At an early age there was seen in this child that prodigious aptitude for all mental labor, which still later formed one of the distinctive traits of his genius. Everything aroused, everything excited his activity. A copy of Buffon, which he finds by chance in the library of one of his relations, suddenly kindles his taste for natural history. He immediately sets about copying the figures and coloring them from the descriptions—a labor which, at so early an age, certainly denoted a sagacity of observation of a high order.

The residence of the young Cuvier at the academy of Stuttgard is too well known to be long dwelt upon. The sovereign of a small state, Charles, duke of Wurtemberg, seemed to have proposed to show to the greatest nations what they might do for the instruction of youth. There were here collected in a magnificent establishment more than 400 pupils, who received the lessons of more than 80 masters. Here were trained, at the same time, painters, sculptors, musicians, diplomatists, jurists, physicians, soldiers, professors in all the sciences. Of the higher faculties there were five: law, medicine, administration, military art, and commerce. The course of philosophy finished, the pupils passed into one of these faculties. Cuvier chose that of administration, and the motive he assigns for it should be reported: "It was," he says, "because in this faculty there was much to do with natural history, and, consequently, frequent opportunities of herborizing and of visiting the cabinets."

Everything in the life of a great man interests us, but doubly so whatever serves to throw light on the process of his labors. We would gladly follow him through the whole course which he has traversed in changing the face of the sciences, and even from his earliest steps would divine something of the direction and character of his thoughts. It has just been seen that our naturalist, yet a child, at sight of the first figures of natural history which fall into his hands, at once conceives the idea of coloring them after the descriptions. While still at Stuttgard one of the professors, whose lectures he had translated into French, makes him a present of Linnaeus. It was the tenth edition of the *Système de la nature*, and this book forms, for ten years, his whole library of natural history. But, in default of books, he had the objects; and this direct, exclusive study

* His name in full was Georges Léopold Chrétien Frederic Dagobert.

of the objects engraved them much better in his mind than if, to use his own expression, he had had at his disposal any number of prints and descriptions. Besides, having neither figures nor descriptions he made them for himself.

Still, all these excursions into natural history had not interfered with the prescribed studies; he had borne off almost all the prizes; had obtained the order of *chevalier* which was accorded to only five or six of all those young persons; and, according to appearances, he might have promptly obtained an appointment. But, fortunately for him and for natural history—and these two destinies were thenceforth inseparable—the situation of his parents did not permit him to wait. It was necessary for him to decide, and the place of preceptor having been offered to him by a family of Normandy at the moment when he was quitting Stuttgard, he hastened to accept it, and at once set out for Caen, where he arrived July, 1788, being then something less than 19 years of age.

From this moment his passion for natural history acquired new force. The family of Herici, to which he was attached, went to reside at a country seat of Caux, a short distance from Fécamp. It was here that our young naturalist lived from 91 to 94, surrounded, as he says, with the most diversified products, lavished upon him, as if in emulation, by the sea and land; always in the midst of such objects, almost without books, having no one to whom he could communicate his reflections, which, therefore, only acquired the greater depth and energy. It was at this period, in effect, that his mind began to open for itself new paths; it was then that at the sight of some *terebratulæ,* disinterred near Fécamp, he conceived the idea of comparing fossil with living species; that the dissection of some mollusks suggested to him that other idea of a reform to be introduced in the methodical distribution of animals; so that the germs of his two most important labors, the comparison of fossil with living species, and the reform of the classification of the animal kingdom, ascend to this epoch.

From this epoch also date his first relations with M. Tessier, whom the storms of the revolution then retained at Fécamp, and who had there occupied for some time the place of physician-in-chief of the military hospital. M. Tessier could not see the young Cuvier without being struck with the extent of his knowledge. He first engaged him to deliver a course of botany to the physicians of his hospital; he afterwards wrote to all his friends in Paris to impart to them the happy discovery which he had made, and especially to those of the *Jardin des Plantes,* who at once conceived the idea of calling the young naturalist thither as assistant of Mertrud, then in charge of the department of comparative anatomy. "Often," says M. Cuvier, in reference to this circumstance, "has a phrase of M. Tessier, in his letter to M. de Jussieu, recurred to me: *You remember*, he said, *that it was I who gave Delambre to the academy; in another walk this also will be a Delambre.*" It was to M. Tessier, therefore, that the Academy of Sciences owed both Delambre and Cuvier. A man who should have rendered but these two services to the sciences might count on the respect and gratitude of all who cultivate them. But how much more vividly do such incidents touch us when they embellish a life wholly consecrated to science, its progress and application, and spent in a long succession of useful labors and virtuous actions!

It was said by Fontenelle to be a piece of good fortune on the part of savants, whom their reputation might afterwards call to the capital, to have had leisure to lay up a good stock of funds in the repose of a province. M. Cuvier's stock was so good that some months after his arrival in Paris, in 1795, his reputation already equalled that of the most celebrated naturalists, and the same year, which was also that of the creation of the National Institute, he was named adjunct of Daubenton and Lacépède, who formed the nucleus of the section of zoology. The year following he commenced the courses which became so rapidly celebrated at the central school of the Pantheon. In 1799, the death of Daubenton led to his appointment to the much more important chair of natural history at the college of France; and, in 1802, Mertrud being dead, he became titular professor at the *Jardin des Plantes.*

It will be recollected that the functions of secretary of the Institute were at first temporary. M. Cuvier was called, among the first, to fulfil these functions in his class, and soon afterwards, in 1803, a new organization of the learned body having re-established the perpetuity of these offices he was chosen perpetual secretary for the physical or natural sciences, with nearly entire unanimity.

It was in this new capacity of perpetual secretary that he composed his memorable *Report on the progress of the natural sciences since* 1789. Delambre had been charged with the report on the mathematical sciences, and thus each class of the institute was called upon to present one on the sciences or arts which fell within its province. It is well known with what state the Emperor received these reports. The peculiar satisfaction which that of M. Cuvier gave him was expressed by a happy turn of words. "He has praised me," said the imperial personage, "as I like to be praised." "And yet," remarks M. Cuvier, "I had done no more than invite him to imitate Alexander, and to make his power instrumental to the progress of natural history." But this sort of praise is precisely that which must most flatter a man who had comprehended all kinds of glory, and would willingly remain a stranger to none. We are at liberty to think, morover, that the praise which has no other object but to induce a sovereign to do worthy things is not unworthy of a philosopher.

To all these occupations, as historian of the sciences, perpetual secretary, professor at the Museum and at the College of France, M. Cuvier added several others. He was named member of the council of the University in 1808, and master of requests in 1813. Nor was the Restoration insensible to his merit. He preserved his position, and was even invested with new functions. Appointed successively counsellor of state,* president of the commission of the interior, chancellor of public instruction, and finally, in 1831, peer of France; his genius embraced all orders of ideas and lent itself to all kinds of labor.

It may well be supposed that he was a member of all the learned Academies of the world; for what Academy could have afforded to omit the inscription of his name on its list? And that which is an honor, of which there were few examples before him, he belonged to three Academies of the Institute, the *Academie Française*, the Academy of Sciences, and that of Inscriptions and Belles-letters.

His great renown brought to him, from all parts, whatever occurred in the way of observation and discovery. It was, moreover, in great part his genius, his lectures, his works, which animated all observers, and everywhere created them; and never could it have been said of any man with more truth than of him, that nature heard herself everywhere interrogated in his name. Hence there is nothing comparable to the rich collections which he created at the museum, and which were all placed in order by him. And when we think of that direct study of objects which was the principal occupation of his life, and through which he has occasioned the outgrowth of so many results, it cannot surprise us that he was often heard to say: "That he believed himself to have been not less useful to science by his collections alone than by all his other works."

In the course of a career so full of success and of honors, M. Cuvier had sustained not a few severe blows. He had lost his first two children, either a few days or a few years after birth; the third, who was a son, died at the age of seven, and all these sorrows were renewed, and with far more bitterness, when he lost his daughter, a young lady of rare qualities, who offered, not only in mind but in features, no faint resemblance to her father. In all the misfortunes of life his consolation was ordinarily sought in redoubled labor; but a consolation still more efficacious consisted in the affectionate attentions with which his family, and above all, Madame Cuvier, were sedulous to surround him.

If we consider the numerous public appointments of M. Cuvier, his uninter-

* He was also *baron* and *grand officer* of the Legion of Honor. It is well to recall these titles; a nation honors itself by thus bestowing them.

mitting researches, his voluminous and important works, it seems astonishing that a single life could have sufficed for so much. But, besides the superior faculties of his understanding, he possessed an ardent curiosity which impelled him to the pursuit of all knowledge; a memory which partook of the wonderful, and a facility even still more wonderful of passing from one labor to another immediately, without effort; a singular faculty, and which, perhaps, contributed more than any other to multiply his time and his energy. Moreover, no one ever made so thorough, and, if I may thus express myself, so methodical a study of the art of not losing a single moment. Each hour had its stated labor; each labor had a cabinet which was destined for it, and in which all was found that related to that labor; books, drawings, objects. Everything was prepared, everything foreseen, so that no external cause might intervene to distract or retard the mind in the course of its meditations and researches. The address of M. Cuvier was grave, and his was not a politeness which diffused itself in words, but he possessed a goodness of heart and a kindness which were prone to proceed always directly to action. It might be said that in this kind also he dreaded any loss of time.

I need not, in concluding, recall to my auditors that death, so much deplored and so sudden, which surprised him in the midst of so many labors and great designs. That event is too recent, the remembrance too painful, and the regrets of his colleagues in this Academy, still vivid and profound, are the homage most worthy of his memory.* Besides, in my feeble sketch of the labors of this great man, I have less considered the man than the savant. I have chiefly sought to retrace that series of sublime truths for which the sciences are indebted to his genius, a genius which is henceforth immortal.

His glory must increase with the progress of the sciences which he created. Time, which effaces so many other names, perpetuates and surrounds with an ever renovated lustre the memory of those rare individuals who seem to have revealed new activities in the intellect, and to have given new forces to thought. And as their minds, outstripping their age, had posterity chiefly in view, so it is only posterity, it is only the succession of ages, from which they can expect all the gratitude and admiration which is due to them.

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* M. Cuvier died Sunday, May 13, 1832.

HISTORY OF THE WORKS OF CUVIER.*

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I.—OF METHOD CONSIDERED IN ITSELF.—RATIONAL METHODS.—EMPIRICAL METHODS.

Method is a part of logic; it is the approximation of like things, and the separation of things unlike. Hence, there have always been methods, especially in natural history, where the number of objects is so great. It was in vain, then, for Buffon to revolt against methods; in proportion, as passing from quadrupeds to birds, he sees the number of species increase, he himself resorts to methodical approximations; he groups together like *species*, he constitutes *genera;* "he silently submits," says M. Cuvier, "to the necessity imposed on all of us, of classifying our ideas in order clearly to represent to ourselves their *ensemble*, their collective import." Aristotle himself had a method, and indeed an excellent one, at least for *classes*.† He knew that the cetacea are mammiferous ‡ he distinguishes in *animals with white blood*, the mollusca, the crustacea, the insects, &c.§ After the revival of letters the learned were content at first with the method of Aristotle; but it was soon found necessary to extend it.

Natural history always resolves itself into *specific objects*. Method really aids us only in so far as it leads to species; and since it should lead to species, it is necessary that it should embrace all species. Now, before Linnæus, it was customary to stop, in several classes, at the genera; in other classes, while proceeding to species, only a few were particularized. Linnæus proposed that *method*, the *distinctive catalogue* of beings, should embrace them all; no species, therefore, was neglected; all were studied, independently of their shape, size, relative utility; all were named. Twenty years after Linnæus, the number of known beings was quintupled.

On the other hand, *specific names* did not yet exist, only *generic* ones. Linnæus founded a nomenclature. Each species had two names: a *substantive* name for the genus, an *adjective* name for the species.‖ The name of the species no

* From the "Histoire des Travaux de Georges Cuvier," by M. Flourens, late perpetual secretary of the French Academy of Sciences, &c.

† See the fine eulogy of M. Cuvier himself on the principles of Aristotle: "Far be it from us to detract from the glory of the great philosopher whom we recall. We think, on the contrary, that it is necessary to revive his principles, if we would give to natural history all its perfection, and we observe with satisfaction that they are beginning to revive." A surprising thing, surely! Aristotle had already discovered the great principles of the science twenty centuries ago; and to rediscover those principles we must come down to Cuvier.

‡ "The dolphin," he says, "has teats, and suckles its young."—*Hist. of Animals, Book II.* External differences do not, in his eyes, mask internal resemblances; he places the serpent, which has no members, by the side of the lizard, which has. "The serpent," he says, "entirely resembles the lizard, by supposing the latter to be lengthened and retrenching its feet."

§ The strong envelope of the shell, however, imposes on him; and to the four natural classes: *mollusks, crustacea, insects* and *zoophytes*, he improperly joins that of the *testacea*. Still, an attentive perusal of the work of Aristotle shows us a surprising number of just conceptions, even in what may be called the anatomy of detail. "The ear," he says, "has no opening into the brain, but into the palate of the mouth."—*Hist. of Animals, Book I.* This was a plain indication of the eustachian tube.

‖ It is this second name, proper to the species and commonly an adjective, which Linnæus calls the *trivial* name.

longer changed, for species is a thing fixed and changes not; but the name of the genus might change, for the genus only denotes relations, and relations may vary in proportion as the number of species varies. These simple ideas had, till then, not been comprehended.

But Linnæus, who rendered these two great services, is perhaps, of all naturalists, he who most contributed to the prevalence, at least for a certain time, of the use of *artificial* methods. Now, an artificial method gives only the name of species; the *natural* method alone gives the name and the relations of species. An artificial method may conduct to names, even while placing in approximation objects the most dissimilar, and for the very reason that it gives only the name of objects. Thus the connections not being consecutive, the artificial method is not of a logical order. That method is alone logical in which species the most similar are placed beside one another, and species the most unlike are furthest removed from one another. Each group therein has the greatest possible number of common properties. And if the groups are contained one in another, if we ascend from one to others by a series of propositions more and more general, we possess the science entire. But what are the means for arriving at this logical or natural method? These means are of two orders: *rational* or *empirical*.

An organized being is a whole; its different parts, therefore, have necessary relations to one another. Now, the more important any part, that is to say, the more essential by the order of its functions, the more do its modifications involve corresponding ones in all the rest. Everything, therefore, consists in knowing the relative importance of the parts, and in subordinating one to the other in the method, as they are subordinated in the organization itself. In this resides the whole rational principle of method. Thus, the *nervous centres*, the *brain*, the *spinal marrow*, by which the animal is essentially what it is, give the first groups of the method; the *respiratory* and *circulatory* centres, the *lungs*, the *heart*, by means of which it partakes of its present life, give the second; the *digestive centres*, by which it sustains that life, give the third, and so on in succession.

The naturalists have only succeeded by long tentatives in conducting the distribution of animals to the point of perfection which it has reached; they have arrived at that point *a posteriori*; they might have arrived at it *a priori*, by the direct determination* of the relative importance of the organs. Now, so far as the *relative importance* of the organs is known, we have a rational method; a method *a priori*. When the relative importance of the organs is not known, we are guided by their *constancy;* we have then only a method *a posteriori*, an *empirical* method. The most *constant* organ is regarded as the most *important;* the constancy of a relation, taken as a fact, supplies the *reason* of that relation, until that reason is known.

Thus, for example, all ruminating animals have the foot cloven; all animals which have horns, ruminate, &c. These are constant relations, but what is the reason of this constancy? We know it not. And yet, since these relations are constant, we may employ them, with confidence, in our methods. Again, insects which breathe by means of tracheæ, are deficient in conglomerate and compact glands. Their secretory organs are only canals or simple tubes. We know at present the reason of this fact. It is because animals which respire by tracheæ have no circulation, and there needs a circulation to make the blood penetrate into conglomerate and compact glands. But before the reason of the fact was known, the fact itself was known; it was shown to be constant; and from the very circumstance of its being constant, it might thenceforth be employed in method. *Constancy*, therefore, represents *importance*.

Thus, there are two kinds of method, or, to speak with more exactness, there

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* *Direct determination*, which is only obtained through physiology. And herein, as has been already said, is the true secret of the great results obtained by M. Cuvier. It was because his vast genius embraced all—anatomy, physiology, zoology; and made each of those sciences co-operate in turn to the progress of the others.

are, for method, two distinct states: the *rational* and the *empirical*. And as method is always bound to be *natural*, when, in order to become so, it has no longer the rational way, it becomes so by the empirical way; when it has no longer the known *importance* of the organs to direct it, it is guided by their *constancy*.

II.—CLASSIFICATION OF THE ANIMAL KINGDOM.

* * * Linnæus divided the animal kingdom into six classes: *quadrupeds, birds, reptiles, fishes, insects,* and *worms*. No precise limit circumscribed these classes in which the cetacea were found among the fishes; the cartilaginous fishes among the reptiles; the crustacea, the articulated worms, animals which have a true circulation, were ranged among the insects which have none; and the intestinal worms, the polypes, the infusoria, the mollusks, even certain fishes were united and confounded in the class *vermes*, the last and most chaotic of all. * * Into this class, in effect, Linnæus had introduced endless confusion, and Bruguières left it just as Linnæus had done. So little attention was still paid to the internal organization of these animals that the last-named author, for example, taking for mollusks all that had no shell, separates from the class in question, under the name of testacea, all that have a shell, as if the slight external character of having a shell hindered the testacea from being true mollusks by virtue of their entire nature or internal organization.

It was in 1795 that M. Cuvier pointed out the extreme difference of the objects confounded in this class, and separated them distinctly, one from another, after a detailed examination and agreeably to characters derived from their organization itself. This examination produced a new general distribution of *animals with white blood* into six classes, mollusks, crustaceans, worms, insects, echinoderms, and zoophytes. From this new distribution of the white-blooded animals dates the revolution of zoology.

Still later M. Cuvier associated the crustaceans with the insects, on account of the common symmetry of their parts, and the articulated structure, alike common, of their members and body; he separated the *annelids*, or worms with red blood, from the intestinal worms; for he pointed out that the former have a true circulation, a distinct nervous system, an articulated body, while the others have neither circulation nor distinct nervous system, nor body properly articulated. He showed that the mollusks, which have so rich an organization, a brain, eyes, often very complex, sometimes ears, always numerous secretory glands, a double circulation, &c., should in the first place be raised greatly above the polypes and other zoophytes, the greater part of which have not even distinct organs, and with which, nevertheless, they had been so long ranged; and, in the next place, that the collective assemblage of these mollusks formed a *group* which, by the importance of its general characters and the number of species which compose it, corresponds not to such or such a class or fraction of the vertebrate animals, but to all the vertebrata joined together; and then, taking up each of the great masses of the animal kingdom, he saw that scarcely any of the general divisions theretofore admitted could be sustained, at least with the characters and limits which had been thus far assigned to them. For instance, it was customary to oppose the *vertebrate animals* to the *animals without vertebræ*, as if these two divisions had been of the same rank; and to designate equally by the name of *class* the whole of the mollusks and a mere fraction of the vertebrata, as if, in effect, the whole body of mollusks was only equivalent to a fraction or subdivision of the vertebrata, &c. Now, since the infinitely varied organization of the animals without vertebræ was at last known, it was impossible any longer to pretend that there was not, between all these varied animals, vastly more difference than between certain vertebrates and certain others. But if, of these two divisions, one comprised structures far more varied than the other, the one could not be equivalent to the other; they were not of the same rank; they should not then

be called by the same name. In like manner, since the organization of the mollusks had become known, it could no longer be pretended that there were not between these animals many more differences than between the animals of a single class of vertebrata; and consequently again, since there was no *parity* between the beings comprised in these two *divisions*, there was no parity of division, and there ought, therefore, to be no parity of name.

But this was not all. By still comparing the structures, and taking them for a guide, it was not less evident that the *crustaceans* united to the *insects*, and these two groups to that of the *worms with red blood*, or *annelids*, formed by their importance, by the number of their species, by their structures so essentially diverse, a third division, similar either to that of the vertebrata or to that of the mollusks; and that all other animals, united thenceforth under the name of *zoophytes*, formed a fourth division similar to each of the three preceding. Considered under this new point of view the animal kingdom presents therefore four grand divisions or *branches*: that of the *vertebrata*, that of the *molluscas*, that of the *articulata*, and that of the *zoophyta*.

Each of these divisions is formed on a particular and distinct plan; that is to say, one which cannot be reduced to that of the others; and they are all like one another in being of the same order; that is to say, that the beings they include present, in their structure, similar or equivalent resemblances or differences. Thus the vertebrata have their plan, the mollusks have theirs, the articulata, the zoophytes have theirs, and all these plans are alike circumscribed; that is to say, that no shading, no intermediary, no lien, can make them pass from one to the other without a rupture, without a *saltus*. A kind of circumvallation separates them. We can pass by modifications more or less graduated from *man*, considered in his organization to the other mammifers, from mammifers to birds, from birds to reptiles, from reptiles to fishes; but from fishes to mollusks, from mollusks to articulata, from articulata to zoophytes, there is no longer any gradation or natural transition. All at once the plan changes and a new form shows itself; but taken in itself this new form, this new *type*, is equally constant, prevalent, uniform; all the mollusks repeat as exactly their own type as the vertebrata, the articulata, the zoophytes, repeat theirs. Thus, in the immense chain of the animal kingdom there are four great forms, four grand types, and there are but four.

This capital fact is equally worthy of note whether we consider it as showing that, with the exception of a few secondary modifications, all animals enter exactly into one or the other of these great forms, or whether we consider it as showing that between each of these great forms there is no shading, no gradation, no intermediate form. The *vertebrata* alone have a spinal marrow, a long medullary cone, into the sides of which enter the nerves, and which is enlarged at its anterior extremity to form the encephalon; they alone have a double nervous system, that of the spinal marrow and that of the great sympathetic; they alone have a canal composed of bony or cartilaginous vertebræ. But all of them have this spinal marrow, this great sympathetic, these vertebræ; all have senses to the number of five, horizontal jaws to the number of two, red blood, a muscular heart, a system of chyliferous and absorbent vessels, a liver, a spleen, a pancreas, kidneys, &c. In a word, the more we examine their whole organization the more resemblances do we discover.

But the more differences do we also find as regards the other *embranchments*. The *mollusks*, for example, have also a brain, though infinitely reduced; but they have no spinal marrow, and consequently no vertebræ; they have no great sympathetic, and their single nervous system, instead of being placed above the digestive canal, as in the vertebrate animals, is always placed, with the exception of the single ganglion which represents the brain, below that canal, being consigned to the viscera; in fine, they have neither a true skeleton nor absorbent vessels, nor spleen, nor pancreas, nor *vena-porta*, nor kidneys; the organ of smell

is wanting in all; that of sight in many; a single family possesses that of hearing, &c., but they all have a complete and double system of circulation, circumscribed respiratory organs, a liver, &c. In a word, if, by the want of a spinal marrow, of vertebræ, of a skeleton, a great sympathetic, &c., they differ essentially from the *vertebrates*, they seem, by the richness of their vital organs, by their double circulation, their respiration, their liver, &c., to come immediately after them, and hence to deserve to form the second of the four branches of the animal kingdom.

The third, or that of the *articulata*, differs not less from that of the *mollusks* than these differ from the *vertebrata*. The animals of this branch have a small brain like the mollusks, and this small brain is also situated upon the œsophagus; but, what is wanting in the mollusks, they have a sort of spinal marrow composed of two cords which run along the belly and unite themselves with it from space to space by knots or ganglions from which issue the nerves; and yet this spinal marrow, which distinguishes them from the mollusks, does not associate them with the vertebrates, for, inversely as regards that of the vertebrates, always placed above the digestive canal, it is always placed below. By an opposite inversion the heart, which is below this canal in the *vertebrata*, is above in the *articulata;* and what I have just said of their spinal marrow may be said of their skeleton, when they have one; it is that this skeleton, while it divorces them from the mollusks, is not a feature which unites them with the vertebrates; for, inversely to that of the vertebrates, which is internal and covered by the muscles, it is external and covers the muscles. Again, in a word, the features which separate the articulata from the mollusks are essential and profound, and such as decide the nature of beings, and the features which seem to connect them with the vertebrates do so only in appearance.

The fourth branch presents characters not less circumscribed, not less determinate than the others. The first of these characters is that all the parts are disposed around a centre, like the radii of a circle; the second is the degradation, the successive simplification of their structure. From the first character is derived the name of *radiata*, or animals of which all the parts are radiate or stellate: and from the second that of zoophytes, or animal plants, animals which, in the simplicity of their organization, approach most nearly to plants. Thus the animal kingdom has four great types or forms, and a little consideration will disclose that each of these general forms of the body depends on the form itself of the dominant system of the animal economy; that is, on the nervous system.

The *vertebrate animals* have a trunk on each side of which all their parts are symmetrically arranged; it is because their nervous system forms a central medullary cone, from each side of which proceed, in symmetrical order, the nerves of all those parts. The *mollusks* have a mass-like body; it is because their nervous system has but a confused arrangement. To the body of the *articulata* some degree of symmetry is restored, but it had been first impressed on their nervous system; the body is articulated externally, for the nervous system is articulated in the interior; in fine, even in the *radiated animals*, whenever the last vestiges of the nervous system are distinguishable it presents that star-like form which is affected by the whole body.

The form of the nervous system, then, determines the form of the animal; and the reason of this is simple: it is that, on the whole, the nervous system is virtually the animal, and all the other systems are present only for its service and sustentation. It is in nowise surprising, therefore, that, the form of this system remaining the same for each *embranchment* of the animal world, the general form of each should remain the same; nor that, this form changing from one *embranchment* to another, the form of each *embranchment* should change.

* * * Having thus seen that the modifications of the nervous system give the first *groups*, the first divisions or embranchments, it follows from the principle of *subordination of characters*, which is but another expression for the subordination of the organs themselves, that the modifications of the organs of circula-

tion and respiration, which come immediately after the nervous system in the order of their importance, will give the first subdivisions, or the *classes*. The *vertebrate animals* present either a simple and complete respiration, with a double circulation, which is the case with the *mammifers;* or a double respiration and double circulation, which is the case with *birds;* or a simple respiration, but complete one, since it is always aerial, and this combined with a simple circulation, being the case of *reptiles;* or a double circulation, combined with an incomplete, that is to say an aquatic, respiration, which is the case with *fishes*. Hence the vertebrate animals are distributed, according to their organs of circulation and respiration combined, into four classes—the mammifers, birds, reptiles, and fishes.

So it is, also, with the *mollusks;* some have three hearts, others two, others one: of these hearts there are such as have but a single ventricle and a single auricle; others a single ventricle and two auricles; others, again, a single ventricle without an auricle, &c.; in fine, certain mollusks respire by a pulmonary cavity, others by branchiæ, &c.; and it will be readily conceived that the combination of all these variations of respiratory and circulatory organs will furnish classes of mollusks as it furnished the classes of vertebrata. The classes of mollusks, thus determined, are six in number—*cephalopods, gasteropods, acephalates, pteropods, brachiopods*, and *cirrhopods*.

The combination of the organs under consideration will give us, likewise, and in even a still more striking manner, the subdivision of the third *branch* into four classes: the *annelids*, whose blood is red like that of the vertebrata; the *crustacea*, whose blood is white like that of all other animals without vertebræ, and which, moreover, have a heart placed in the back, &c.; the *arachnids*, which have for heart only a simple dorsal vessel which sends forth arterial branches and receives venous ones; and *insects*, which have no vessels at all, neither arteries nor veins, which have only the vestige of a heart, and whose respiration is not effected by circumscribed organs, but by *tracheæ*, or elastic vessels distributed through the whole body. In this *branch* of the *articulata* we observe, therefore, the transition from animals which have a circulation to those which have none, and the corresponding transition from those which respire by means of circumscribed branchiæ to those in which tracheæ distribute the air to every part.

It is in the fourth *branch*, or that of *zoophytes*, or the *radiata*, that we observe the disappearance, the gradual and successive fusion of all the organs into the general mass. Thus, some of these animals have still closed vessels, distinct organs of respiration, &c.; others, which have neither such vessels for circulation nor such organs for respiration, have still visible intestines; it is only in the last of all that everything seems reduced to a homogeneous pulp; and it is on the different degrees of complication in their structure that is founded their subdivision into five classes: *echinoderms, intestinal worms, acalephs, polyps*, and *infusoria*. * * * * * * *

Thus the nervous system has furnished the *branches;* the organs of circulation and respiration combined, the *classes;* and it is easy to conceive that organs more and more subordinate would successively supply the *orders*, the *families*, the *tribes*, the *genera*, the *sub-genera*, in a word, the whole scaffolding of the method. Thus as regards the *mammals*, for instance, (for it would detain us too long to follow the unfolding of the method in all the classes,) the combined organs of *touch* and of *manducation* divide this *class* into nine *orders: man*, who has three sorts of teeth, (molar, canine, and incisive,) and who has the *opposable thumb* on the two anterior extremities alone; the *quadrumana*, which have also the three sorts of teeth, and, moreover, the opposable thumb on the four extremities; the *carnivora*, which again have the three sorts of teeth, but no opposable thumb and consequently no *hands*, which have only *feet*, but feet of which the digits or toes are movable, like those of the two above orders; the *rodents*, whose

toes differ little from those of the *carnivora*, but which have only two sorts of teeth, the molar and incisive; the *edentata*, in which order the toes have become less movable, and are almost confounded with large claws, and which have never any teeth but the molar and canine, sometimes only molar, and sometimes none at all: the *marsupials*, or *animals with a pouch*, a small series collateral to the three preceding orders, some of them corresponding to the carnivora, others to the rodentia, and others to the edentata; the *ruminants*, which form a strikingly distinct order in view of their cloven feet, their upper jaws without true incisors, their four stomachs; the *pachydermata*, which comprise all the other quadrupeds with hoofs; and the *cetacea*, which are wholly destitute of posterior extremities.

The principal modifications of the combined organs of touch and manducation having given the *orders*, secondary modifications of these same organs will supply the *families*; and modifications more and more subordinated will give all the other groups, the *tribes*, the *genera*, the *sub-genera*, until we finally reach the *species* for which the whole scaffolding is constructed.

Thus, to confine ourselves again to a single order of the mammifers, that of the *carnivora*, for example, it has just been seen that one of the characters of that order is to have *movable* toes. Now, if we suppose these toes to have become very long, and to be united by membranes, so as to form an organ of flight, as in the bats, we shall have the *family of cheiroptera*; if we suppose that the animal, the toes remaining free, supports itself in walking on the entire sole of the foot, or, on the contrary, that it walks only on the ends of its toes, we shall have in the first case the *tribe of the plantigrades*, and in the second that of the *digitigrades*. And similarly as regards the organs of manducation, it has been seen that this order has three sorts of teeth, and it is this which constitutes its character as an *order*; but let us suppose that the molar teeth (which by their form always decide the diet of the animal) are feeble and furnished with conic points, and we shall have the *family of insectivora*; or that these same teeth have become stronger, and, instead of simple conic points, are armed with parts more or less incisive, and we shall in that case have the *family of carnivora*; and in this latter family, according as the molar teeth are entirely cutting or incisive, or more or less mingled with blunt tubercles, we shall have either the genus *bear*, of which almost all the teeth are *tubercular*; or that of *dogs*, which have only two tubercular; or that of cats, &c., which have none tubercular, and which consequently are exclusively carnivorous, while the dog is capable of receiving a certain amount of vegetable nourishment, and the bear may be entirely nourished on vegetable food. And herein lies one of the *necessary relations* between the organs which enables us to calculate with considerable certainty the proportions of the alimentary canal, from the extent of the tubercular surface of the teeth of animals, compared with the cutting or incisive surface.

What has been here said might be easily exemplified as regards all other families, tribes, and genera; and it will hence be seen that the simple placing of an animal in one of these *groups*, teaches us as exactly as the most detailed description, all that relates to the organization of that animal, or to the degree of organization which corresponds to the group in which it is placed. Let me be told, for instance, of some creature that its place is in the genus *cat*, and I shall at once conclude not only that its molar teeth are all sharp or incisive, as being a *cat*, but further, that it has *three sorts of teeth*, *movable toes*, *&c.*, as being *carnivorous;* that it has a double circulation and a complete respiration, as being a *mammal;* that it has, also, a spinal marrow, a canal composed of vertebræ, five senses, &c., as being one of the *vertebrata*. Thus I shall know the whole of its organization from its place alone, and what will remain for me to say of it will, of course, be reduced to a few words, for the indication of its proper or specific characters.

Now, as the number of known beings is immense, and, immense as it is, cannot fail to be much more augmented, we perceive the advantage of being able

thus to substitute a few words for a complete description; of having to say nothing of each species but what is proper to it; of being able to supply, by its place alone, all that it has in common with all the rest of the kingdom; but we also perceive that, for method to afford this advantage, it is necessary both that all its *groups* should be rigorously subordinated among one another, and that each of them should comprise only beings of the same structure.

Groups well constituted, alone admit of general propositions. Without general propositions there can be no method; without method no brevity; the highest merit of all science in which the number of facts is immense, as it is in every branch of the history of the beings of nature. A *genus*, a *family*, an *order*, ill-constituted, stands in the way of every general proposition relating to that genus, family, or order. Thus, by placing the *siren* and the *eel* in the same genus, Gmelin rendered it impossible to say anything general upon that *genus;* by placing the *cuttle-fish* and the *fresh-water polyp* in the same order, he made it impossible to say anything general upon that *order;* and by placing the *mollusks*, the *worms*, and the *zoophytes* in the same class, Linnæus had rendered every general proposition relative to that *class* impossible, &c.

By means of well-constituted *groups*, then, we are enabled to say, at one time, for all the species they contain, what it would have been necessary, otherwise, to repeat as many times as there had been species remaining dispersed and detached. But, among all these *groups*, and under the point of view with which I am here concerned, the *genera* have an importance which is proper to themselves. It is, that being the *first approximation of species*, all the rest of the scaffolding is, so to say, founded upon them, and an ill-constructed genus would suffice to break the *unity* of a *family*, of an *order*, of an entire *class*. Besides, being nearer to the *species*, the more they shall combine only such species as are conformable with one another, the less there will remain to say for each of them; and it is herein that may be seen all the inconvenience of those *large genera*, into which, even of late, so many incongruous species have been thrust, and all the advantage of intersecting those genera by *sub genera*—a happy expedient which forestalls confusion, by approximating in a closer manner the species which present resemblances more particular or more intimate. * * * * * *

But all this work of *genera*, *sub-genera*, &c., of which we have been speaking, supposes a work not less considerable, the positive establishment, namely, of *species*—a point in which the animal kingdom presented not less confusion than in all the others. It was not sufficient to have remodelled or created almost all the divisions of that kingdom; it was incumbent on M. Cuvier to revise all the species, to revise them one by one, and even their *synonyms;* for sometimes several were confounded under the same name, sometimes a single one passed, under different names, for several; and this criticism of so many names, imposed right or wrong, on such a number of species, was assuredly neither the part of the work which offered least difficulty to the author, nor that which has saved his successors least embarrassment. It suffices, in effect, to cast the eyes on the works upon natural history which have appeared since the first edition of the *Règne animal*, to see the happy fruits which have resulted from these labors upon synonyms of which I now speak, and that art of establishing divisions in the comprehensive *genera* of which I had been previously speaking.

I have said, with reference to *branches*, and again with reference to *classes*, that each of these groups is definitely circumscribed; as much may be said of all other groups in every degree. Linnæus had pronounced that "nature makes no leaps;" and Bonnet, that "the chain of beings is but one continuous line." The very reverse of these propositions would be much more exact. The truth is, that the different groups are separated from one another by intervals more or less marked and profound; and there is, in the very organization of the animals, an evident reason for all these intervals.

The organization of an animal is only, in effect, a certain combination of organs;

but all combinations of organs are not possible. For example, a *stomach* of one of the *carnivora* necessarily supposes *incisive* teeth for rending its prey, *movable* toes for seizing it, &c.; for a like reason, animals with hoofs are, of necessity, all *herbivorous*, because their immovable toes would not allow of their seizing a living prey—their molar teeth, with a flat crown, could not tear it, &c. There is a necessary harmony, therefore, which regulates the combination of organs; there are such as exclude one another, such as necessitate one another, so that all combinations are not possible; and it necessarily follows, if only from the fact that all combinations of organs are not possible, that there must be certain gaps, certain chasms between the possible combinations and the impossible, or between different groups of creatures; and that this sort of *hiatus* is determined by the laws or conditions under which these creatures exist.

The first edition of the *Règne animal* (which itself succeeded the *Tableau élémentaire de l'histoire naturelle des animaux*, wherein the first germs of Cuvier's ideas on classification had been developed) occupied but four volumes, the second five; of which the last two, relating to the *crustaceans*, the *arachnids*, and the *insects*, were the work of M. Latreille, who, as M. Cuvier himself pronounced, had, "of all the men of Europe, studied those animals the most profoundly." It may well be supposed that a work of the nature of that of which we speak, a work which, on its appearance, became at once the guide of all zoologists, would be translated into all languages. It was so, in effect, into English, by M. Griffith; into Italian, by the Abbé Ranzani; and into German, by M. Schinz.

III.—NATURAL HISTORY OF FISHES.*

This work may be considered under two distinct relations: under that of the great number of new species with which it has enriched zoology, and under that of the application which the author has therein made of the *empirical laws* of method to a definite class of the animal kingdom. I shall say but a few words on the work considered under the former point of view, which would adapt itself but little to the philosophical studies which I have in hand.

Aristotle knew and named 117 kinds of fish; Pliny knew but 95 or 96; Oppian names 125; Athenæus, 130; Ælian, 110; Ausonius names for the first time the salmon-trout, the common trout, the barbel and some other fresh-water fishes. In all, the ancients had distinguished and named 150 species of fish; only about 40, therefore, had escaped the research of Aristotle; and, as regards the structure of these animals, nothing was added to what he had said. In the middle of the 16th century Rondelet, Belon, and Salviani make their appearance; the three original authors who founded *ichthyology*. Belon describes and names about 130 fishes; Salviani, 99; Rondelet, 244, of which 197 belong to the sea and 47 to fresh water. Neglecting some secondary authors, if we come to Ray and Willoughby, we find the number of known fishes already more than 400; the same is nearly the case with Artedi and Linnæus; there are about 1,400 in Bloch and Lacépède; there are nearly 5,000 in the work of M. Cuvier. * * * *
But to come at once to the philosophical part of the work under consideration, we proceed to the distribution of species, or rather to the views which have guided the author in that distribution. Aristotle had recognized that the true characters of fishes consist in the *branchiæ* (gills) and in the *fins*. The class of fishes is composed, therefore, of *vertebrate* animals with these appendages; the features common to all being the *vertebræ*, or, more exactly, an *internal skeleton*, (for the vertebræ do not alone compose that skeleton,) the *branchiæ* and the *fins*. The differential features are an *osseous* or a *cartilaginous* skeleton; gills, now *free*, now *fixed*; fins, *soft* or *spinous*; ventral fins placed by turns *before*, *behind*,

* The first volume appeared in 1828; 8 of the 20 volumes, which the work was intended to comprise, were published before Cuvier's death, and several others have since made their appearance through the care of M. Valenciennes, the coadjutor of Cuvier for the entire work.

or *under* the pectoral; teeth placed by turns on the *intermaxillaries*, the *maxillaries*, the *vomer*, the *palatine*, the *tongue*, the *arches of the branchiæ*, &c.; the form of these teeth, *plate-like*, *villiform*, *pointed*, &c.; the opercula or covers of the branchiæ, whether *smooth*, *scaly*, *serrated*, *sharp-pointed*, and *armed with spines*, or *obtuse* and *without spines*, &c.; and it is on the varied combination of these *differential features* or *characters* that all the different methods which have been successively imagined for the classification of fishes depend.

It will be readily understood that he who should employ but one or two of these characters would have only an *artificial* or *incomplete* method, like Linnæus; that he who should indistinctly employ them all would have only a *confused* method, like so many ichthyologists, and that the *natural* method—that is to say, the exact and complete one—consists at once in employing them all, and in employing none but *according to the relative order of its importance*. There are two points, in effect, which control the whole idea of a natural method: one to employ only *true characters;* the other to accord to each of these characters only the *precise degree of its importance*. But, to employ only true characters—that is to say, not to attribute to such or such a species such or such a character which it wants, and, reciprocally, not to suppose it destitute of such or such another which it possesses—we perceive that it is necessary to know all the species. On the other hand, to attribute to each character only the degree of its importance, we perceive that this complete knowledge of species, in itself so vast and so difficult, still would not suffice, and that it is, moreover, necessary to have compared these characters under all their relations; that it is necessary to have varied, multiplied, exhausted all their combinations.

Now, on these two points which constitute, in fact, the whole of ichthyology—that is to say, both for the *determination of species* and the *valuation of the characters* according to which those species are composed or discriminated up to the time of M. Cuvier—everything was yet to be done. The species of fishes were not known; the proof of it is in every page of the book we are considering. No just idea existed of the characters which decide their union or distribution, the proof of which is found in those perpetual transpositions undergone by the same species in the different classifications of authors. * * * *

IV.—LECTURES ON COMPARATIVE ANATOMY.*—LAWS OF ANIMAL ORGANIZATION.

Two great laws control and comprise all the others; the first is that of *organic correlations;* the second that of the *subordination of organs.*

A necessary *correlation* binds all the functions one to another. Respiration, when executed in a circumscribed respiratory organ, cannot dispense with circulation, for it is necessary that the blood should arrive at the respiratory organ, the organ which receives the air, and it is the circulation which carries it thither; circulation cannot dispense with irritability, for it is irritability which determines the contraction of the heart, and consequently the movements of the blood; muscular irritability, in turn, cannot dispense with the nervous action. And if one of these things is changed, it is necessary that all the others should change. If circulation is wanting, the respiration can no longer be *circumscribed;* it is necessary that it should become *general*, as in insects; the blood no longer seeking the air, it is necessary that the air should seek the blood.

There are organic conditions, therefore, which call for one another; there are such as exclude one another. A circumscribed respiration necessarily demands a pulmonary circulation; a general respiration renders a pulmonary circulation useless, and excludes it. Everything is thus regulated by necessary relations.

* Two volumes of this work appeared in 1800, three more in 1805. In the former, M. Cuvier had for his coadjutor M. Duméril; in the latter series he was assisted by M. Duvernoy, who is publishing at the present time a second edition of the entire work.

The mode of respiration is in constant dependence on the circulation, which carries the blood to the air, or to the organ which receives the air; the force of the movements is in constant dependence on the quantity of the respiration, for it is respiration which restores to the muscular fibre its exhausted irritability.

The quantity of respiration everywhere determines the vigor, the rapidity, and the kind of movement. The movement which requires most muscular energy is that of flying, and the bird has a double respiration. The mammal has movements more limited, and it has a simple respiration. The reptile has movements more feeble still, and it has but an incomplete respiration. The bird respires not alone by its lungs, but by its whole body. The air, after having traversed the lungs, which are transpierced like a sieve, penetrates into the cellules of the abdomen, into the cavities of the bones, &c. It is, therefore, not alone the blood of the lungs, but the blood of the whole body, which respires. The mammal has but a simple respiration, for there is but the blood of its lungs which respires; but this simple respiration is complete, for all the blood of the body passes through the lungs before returning to the members. Finally, the reptiles have but an incomplete respiration; their pulmonary circulation is only a fraction of the general circulation; there is but a part of their blood which respires, or which, returning from the members to the heart, passes from the heart to the lungs before returning to the members. Hence, the reptiles have only cold blood, only slow movements, interrupted by long repose; they are all subject to hibernating torpor, &c. On the other hand, fish have a complete pulmonary circulation; but they have only an aquatic respiration, that is to say, an imperfect one, since they have, for respiring, only the small quantity of air contained in the water; quite the contrary of what has been just said of reptiles, which have an aerial or perfect respiration, and an incomplete pulmonary circulation.

Now, these two things are mutually compensatory: an aerial or perfect respiration is compensated by an incomplete pulmonary circulation, and a complete pulmonary circulation by an aquatic or imperfect respiration. Fish, therefore, have only cold blood, like the reptiles—only movements which require little muscular energy, &c. Thus, there are in vertebrate animals four definite degrees of respiration: the complex respiration of birds, the simple but complete respiration of mammals, and the incomplete respiration, incomplete by two different means, of reptiles and fishes. And there are four kinds of movements which correspond to these four degrees of respiration: the flight of the bird, which corresponds to the duplicate respiration; the step, the leap, the run of mammals, which correspond to the complete, but single respiration; the crawling of the reptile, a movement by which the animal does no more than drag itself along the earth; and the swimming of the fish, a movement for which the animal has need of being sustained in a liquid, the specific gravity of which is nearly equal to its own. And as of movement, so too of digestion. The greater the capacity of respiration, the more rapid the digestion. The most rapid digestion is that of the bird, the slowest that of the reptile; the bird surprises us by the frequency of its repasts, the reptile by the duration of its abstinences.

Everything in the bird is formed for flight. It required a wing of wide surface to strike the air; for this wing large muscles were needed to move it; these muscles required very large bones for their insertion. And the bird has a sternum developed into a salient blade, into a crest, it has a pectoral muscle relatively enormous, &c. So much for the exterior; internally, it has a duplicate respiration, an animal heat and muscular energy which correspond to that respiration; and, for this duplicate respiration, it has lungs perforated like a sieve, *air-cells*, which are the appendix of its lungs, &c. Nor did all this suffice; my own experiments have shown that the brain is composed of three parts essentially distinct:* the cerebrum, exclusive seat of intelligence; the *cerebellum*, seat of the

* See my *Recherches expérimentales sur les propriétés et les fonctions du système nerveux*, &c. Second edition, Paris, 1842.

principle which governs or co-ordinates the movements of locomotion; the *medulla oblongata*, seat of the principle which controls the movements of respiration. Now, in the bird, the part of the brain which, relatively to the brain of other vertebrate animals, predominates, is precisely that which governs or co-ordinates the movements of locomotion; it is the *cerebellum*. All the parts, all the functions, all the modifications of the parts and of the functions, are therefore formed each for the others, and all for a given purpose.

We have seen this as regards respiration, as regards the act of flying, &c. It is easily shown as regards digestion. The system of an animal is, in effect, by no means an arbitrary thing. It is not by hazard that incisive teeth coincide with a single stomach; flat and dull teeth with a multiple stomach; flat teeth, a multiple stomach, with a herbivorous diet, &c. A single one of those things, necessarily supposes all the others, or excludes them all. An animal with long intestines, a multiple stomach, flat teeth, is necessarily herbivorous. A carnivorous animal has, necessarily, incisive teeth, a single stomach, short intestines; it has, moreover, and just as necessarily, divided and movable digits, to seize its prey; and, even in the brain, it has a peculiar instinct which impels it to nourish itself on flesh. Never will such an instinct nor an incisive tooth co-exist in the same animal, with a foot enveloped in horn, for these things are incompatible and contradict one another; the animal in which they presented themselves together could not subsist. The laws of *organic correlations*, properly viewed, are the *very conditions of the existence of beings*.

After the law of *organic correlations*, comes, as we have said, the law of the *subordination of organs*. A recognized subordination everywhere subjects certain organs to others: the organs of locomotion to those of digestion; the organs of circulation to those of respiration; all functions and all organs to the nervous system. Circulation, for instance, does or does not exist, according as respiration is conducted in such or such a manner. All animals with a circumscribed respiration (the vertebrata, the mollusks, the crustacea, &c.,) have, necessarily, a circulation; for it is necessary that the blood should arrive in the organ which receives the air, and it is the circulation which carries it thither. The insects, in place of a circumscribed respiration, have a general respiration, executed by means of tracheæ, which carry the air everywhere; in their case, there was no need of circulation, and there is none.

The same subordination connects the organs of *locomotion* or of *prehension* with the *digestion*. And such is the force of this subordination that one of these organs seems incapable of making any progress without manifesting a similar progress in the other. Thus, for example, the ruminant animals have, in general, neither *canine* nor *incisive teeth* in the upper jaw, and there are but five bones to their *tarsus*; the camel has canines, and even two or four incisives in the upper jaw, and already we observe an additional bone in the tarsus, because the *scaphoid* is here not consolidated with the *cuboid*; further, the common ruminants have, for the whole *fibula*, only a small bone articulated at the base of the *tibia*, and the chevrotain or *moschus*, which has canines well developed, has a distinct and complete fibula, &c.

V.—COMPARATIVE OSTEOLOGY.

This branch of science, sprung from the labors of Daubenton, of Camper, of Pallas, has become, in the hands of M. Cuvier, a new instrument; it was by comparative osteology that he reconstructed the lost species of ancient worlds; and it is well worthy of remark that in this long and laborious series of researches and efforts none of these learned men ever diverged from the domain of positive facts. Such, effectively, is the empire of these facts over the human mind that, except in their default, it scarcely ever throws itself into the domain of conjecture and hypothesis. In almost every line it is only when the facts are not

known, or begin to be exhausted, that recourse is had to systems; and what is unfortunate for the history of science is not the mania of systems, which prevails before the acquisition of facts, but that which seeks to reproduce itself afterwards.

The great work of M. Cuvier on *fossil bones* shows that there is not a single bone, a single part of a bone, of which the study is not valuable, necessary, often indispensable, for the distinction of fossil species from existing species. This work seems everywhere a living proof of the saying of a celebrated writer, that never, except in the profound study of details, have the secrets of nature been surprised; and it cannot be observed without pain that while there remain to be discovered any of those facts of which the least circumstances possess such an importance, so many authors turn away from this curious and solid research for so many other researches as vain as they are idle; these, for example, choosing to discover, in any event, all the parts in each; the entire body in the head, the members in the jaws, the thorax in the nose, &c., those, making by turns the pieces of an apparatus pass into another, in order thus to arrive at a unity of number which this overturning of everything does not itself yield them. The object of M. Cuvier, it may easily be conceived, was not to follow the authors in question into these researches, more hardy than philosophic; he nowhere pretends to find in an apparatus either representations of parts foreign to that apparatus, or constant numbers of pieces or bones, but he seeks how far the correspondence of these pieces goes and where it stops.

At no epoch has it been possible to compare the different beings which compose the animal kingdom without remarking, at the same time, their resemblances and their differences, and the difficulty has never been other than to fix the precise limit between the analogies which constitute, on the one hand, the characters more or less general of species, and the differences which, on the other, constitute their characters more or less distinctive and peculiar. Hence arise two branches of the same study, which both date from the first ages of science; one the search for analogies, the other the search for differences. Now, it is readily conceivable that, according to the epoch, such or such of these researches should appear more or less important in relation to the other; but, at bottom, it is easy to see that one always supposes the other, and that it is neither the evident analogies nor evident dissimilitudes which could ever have been the subject of serious discussion, but, in truth, the real differences hidden under apparent analogies, or inversely, the analogies hidden under differences. In a word, as it is impossible to mark the point where dissimilarity commences without marking that where analogy ceases, it would be impossible to carry the study of differences as far as M. Cuvier has done without recognizing the point where the analogies commence; and perhaps it was necessary, in effect, to exhaust first the study of differences in order to be sure of allowing no analogies afterwards to stand but such as are real and incontestable.

However this may be, the profound sentiment that an immense analogy, or rather that analogies of all kinds bind together more or less all the beings of the animal kingdom, is a sentiment which, as I have just said, dates from the first ages of science. The whole work of Aristotle bears on the conformity of the different species with one another, and of all with man, taken as a common term of comparison. Buffon wonders at the constant uniformity of design, and asks if this latent resemblance be not more surprising than the apparent differences (*Histoire de l'ame*). Daubenton points out the conformity of structure in the greater part of the skeleton, and particularly in the foot—that is to say, the part of the skeleton which varies the most (*Description du cheval*). Camper, in two ingenious discourses,* dilates on the astonishing analogy between the structure

* *Discours sur l'analogie qu'il y a entre la structure du corps humain et celle des quadrupèdes, &c.*—Belon, before Camper, by placing vertically the skeleton of a bird, had rendered conspicuous a multitude of relations till then unnoticed, with the human skeleton. *Histoire de la nature es oiseaux, &c.*

of the human body and that of quadrupeds, birds, and fishes, and shows how, by gradual changes from a horizontal to a vertical attitude, it is possible "to transform a cow into a bird, a quadruped into a man, &c." Finally this striking idea is seen pervading the writings of Vicq-d'Azyr, who says that "nature seems always to work after a primitive and general pattern, from which she deviates only with reluctance; that we observe everywhere those two characters which seem impressed on all beings, that of constancy in the type and variety in the modifications."*

Nevertheless, this opinion of a *constant uniformity of design*, of an *astonishing analogy*, of a *primitive and general pattern*, rested as yet only on a perception vague and more or less confused. And it is in our own times alone that this complicated question of the *analogy of structure* has been disentangled and divided; that it has adopted as a field of discussion determinate and precise facts; that, become a positive question, it is capable of being discussed in a rigorous and detailed manner.

This question has been termed the question of *unity of organization;* it might quite as well have been termed the question of *variety of organization*; all depends in effect on the point of view under which it is considered; for since there are different species of animals, unity here supposes necessarily a certain variety; and since, on the other hand, these different species all resemble one another, at least on that common ground which consigns them to the same kingdom, it is evident that this variety necessarily supposes also a certain unity or conformity. The true title of the question, or rather its true object, was therefore the determination of the limits where stop, by turns, the resemblances and differences in the organization of animals; an organization at once so similar and so varied. Once divided, as I have just said, the question has taken quite another aspect. The general resemblance of animals has been no longer concluded from some particular resemblances, nor limited to certain *branches*, to certain *classes*. As regards the osseous system, for example, it had been presently perceived that, only pertaining to vertebrate animals, this system can only yield results limited to that embranchment, to that type. The resemblances of the osseous system which testify so strongly to a common ground-plan, to a unity of structure, testify to them, therefore, only in reference to the sole type which possesses an osseous system, the type of *vertebrates*.

Considered collectively, the osseous system forms the skeleton, which is divided into several parts: the apparatus of the vertebræ, that of the cranium, those of the face, of the ear, of the hyoide, of the opercula, of the ribs, of the sternum, of the shoulder, of the pelvis, of the limbs. Now, there is not a member of this diversified apparatus which does not, in the different classes, vary in the form, the number, the complication of the pieces which constitute it. For the most part, and saving the variations just spoken of, they are reproduced in all. There are, however, some which are wanting in such and such a class; there are some which are the exclusive attribute of a single one. The question is to see what is the particular character of each apparatus in each class; that is to say, of what pieces it is there composed, what there is the form and the combination of those pieces. Now, such an examination shows that, among all these parts of which the skeleton is composed, some are essential, and hence more constant; others accessory, and hence more variable; that the vertebræ, the cranium, which lodge the spinal marrow, the encephalon, may readily vary from one class to another in the number and form of their bones, but are found in all; that, on the contrary, the ossicles of the ear, the opercula, the limbs, &c., all accessory and subordinate parts, may be wanting, and are so in effect, when the conditions of audition, of respiration, of locomotion, are no longer the same. These are analogies, then, graduated like the importance of the parts which present them; each part has its proper limits, both of variety and analogy; each should be studied apart; and it might hence be said that there is a particular

* See especially his memoir "*Sur le parallèle des extremités, &c.*"

comparative osteology of each osseous apparatus, as there is a general comparative osteology of the whole system.

The *cranium*, that most complicated apparatus of the skeleton, presents, in all mammifers, a composition very nearly the same; we may there follow each bone, from man to the quadrumana, from the quadrumana to the carnivora, to the rodentia, to the edentata, the pachydermata, the ruminants, the cetacea; everywhere are recognized frontals, parietals, occipitals, temporals, the sphenoid, the ethmoid; and they are everywhere recognized as well by their position as their use. It is as much if the interparietals appear to be wanting in certain species. It is the same with the face. The bones of the nose, of the cheek, of the jaws, of the palate, &c., are never wanting. The lachrymals alone fail in the phocæ, the dolphins, &c. All other differences of number are but apparent, and result only from the greater or less promptness with which, according to the species, the bones or parts of bones, constantly separated in the first stage of life, unite and are confounded in adult age. It is thus that, according to the species, the occipital, the parietal, the sphenoid, the temporal, &c., appear sometimes single, sometimes double, triple, or quadruple; but when we recur to the fœtus the occipital is always divided into four parts, the parietal into two, or rather into four, counting the inter-parietals, which, in the end, constantly become united therewith, the temporal into four, the body of the sphenoid into two, &c. Thus, in the mammals, there is a normal number for the bones of the cranium; and when this number appears masked by the obliteration of the sutures in the adult state, the primitive division is always reproduced and restored in the fœtal state; and what I say of the bones of the cranium may be said also of the bones of the face, and of their more numerous subdivisions in the earlier stages.

It would naturally be curious to see whether this singular analogy was maintained in the other classes, in the birds, the reptiles, the fish; whether the same number of bones is there everywhere reproduced; whether, masked in the adult state, it would appear in the fœtal; whether, in fine, reptiles and fish, in which the bones of the cranium are always much more numerous, could be regarded as corresponding in this respect to the early age of birds and mammals. This interesting question was successively treated by M. Cuvier in reference to reptiles (*Reserches sur les ossemens fossiles, tome* 5,) and to fish (*Histoire naturelle des poissons*;) it will suffice to indicate here the manner in which he has resolved it relative to reptiles.

The reptile whose head presents the most striking traits of conformity with that of the mammifers is the crocodile; from the crocodile M. Cuvier passes in succession to the tortoises, the lizards, the serpents, and finishes with the batrachians, which conduct from reptiles to fish, as the crocodile from reptiles to mammals. The head of the crocodile is composed of a much greater number of bones than that of the adult mammifer, but by recurring to the fœtus of this last class we recognize in the head of the crocodile and that of the mammifer very nearly the same number of bones. Thus M. Cuvier, after having found in the crocodile, and in the same place as in the mammals, the intermaxillary bones, the maxillary, the nasal, the lachrymal, the jugal, the palatine, the ethmoid,* the body of the sphenoid, the parietal, finds also, and again in the same place, the occipital, but divided into four parts, as it is in the fœtus of mammals, the great wings of the sphenoid, vestiges of its lesser wings, its internal and external pterygoid wings, but all these parts separate from the body of the bone, as they all are, except the last,† in the mammal at its earliest age; finally a temporal

* With its cribriform lamina, its lateral wings, its superior cornets, its vertical lamina, but all these pieces or dependences of the ethmoid, in great part, in a cartilaginous state.

† For this reason M. Cuvier gives the special name of *transverse bone* to the external pterygoid apophysis, which, in the mammals, is not at any age effectually separated from the great temporal wing. It is, therefore, not properly a new bone, but a dismemberment of the sphenoid, as the frontal bones, anterior and posterior, are dismemberments of the frontal.

bone, but composed of four bones, as it is in the fœtal mammals, the squamosal, the mastoid, the cavity of the tympanum, and the petrous bone. There remained only the bones which correspond to the frontal to reduce to analogy, but these bones are six in number in the crocodile, and as the frontal of mammifers is never divided but into two, M. Cuvier was obliged to admit here a peculiar dismemberment of this bone, a dismemberment which, in the crocodile, or, to speak more generally, in the greater part of oviparous vertebrates, subdivides each of the two frontals of mammals into three others, the principal, the anterior, and the posterior frontals.

This determination of the bones of the head of the crocodile, compared with those of the head of mammals, being once established, it is easy to refer to it, as a sort of type, the bones of the head of all other reptiles, particularly tortoises, lizards, and serpents. Thus, with due regard to the differences of form and proportion, the greater part of the bones of the crocodile reappear in the head of the tortoise; but this head wants the nasal bones, which are here represented only by cartilaginous laminæ, the transverse or external pterygoid and the lachrymal bones. Moreover, the parietal, which is single in the crocodile, is double in the tortoise; but in the lizards this parietal again becomes single, the lachrymal and transverse bones reappear, a new bone is disclosed which M. Cuvier calls *columella*, &c.; all but slight differences, which do not hinder us from recognizing throughout the predominance of one same plan in the heads of the crocodile, the tortoise, and the lizard.

A new and more difficult study commences with the *batrachians*. First, the general composition of the head is singularly simplified. We find here only the two lateral occipitals, with neither upper occipital nor basilar; a single sphenoid with neither temporal nor orbital wings; a single bone replaces at once the principal frontal and the ethmoid; there are no posterior frontals, but there are two anterior frontals, two parietals, and two petrous bones. Nor is the face less simplified, for the transverse forms only one with the pterygoid, the temporal but one with the tympanic, and there is no mastoid. The cranium of the frog, therefore, has but 10 bones, one ethmoid, two frontals, two parietals, two occipitals, one sphenoid, two petrous bones; its face has but 16, two intermaxillars, two maxillars, two nasals, two palatines, two vomers, two pterygoids, two tympanics, and two jugals or zygomatics. In all, its head has but 26 bones, while that of the crocodile has nearly 40. And this difference of number presents itself in each particular apparatus of the face; thus the lower jaw of the crocodile has six bones on each side, and each side of the jaw of the frog has but three, &c.

I have said that the apparatus of the *vertebræ* is, with that of the cranium, the most constant; each vertebra may itself be considered as a small distinct apparatus, composed of a certain number of bones, which is not the same for all the vertebræ in each species, nor for each vertebra in all the species; the atlas of the crocodile has six bones, its axis has five; the atlas of the tortoise has only four, that of the monitor three, &c. But it is chiefly by their total number that the vertebræ vary from one class to the other, and even in the different orders, the different genera of each class. Not to depart here from the reptiles, the crocodile, for example, has 26 vertebræ — 7 cervical, 12 dorsal, 5 lumbar, and 2 sacral; 200 are counted in the adder, the boa, &c.; the frog has but nine. As regards other apparatus of the animal system, being only accessory, the greater part may be wanting, and is wanting, in effect, in such or such a class, such or such an order, such or such a genus, &c. The hinder extremities fail in the cetacea, both the anterior and posterior extremities in the serpent, the ribs are absent in the frog, the auricular apparatus in fishes, &c.

Nothing is better calculated to give a just idea of the manner in which a certain general conformity is combined in certain cases with all the variations of detail than what is seen in the shoulder and the sternum. The *shoulder*, which is composed, in the mammifer, of but one bone, the scapula, or of two, the scapula and

the clavicle, has always three in the bird: the scapula or omoplate, the clavicle, and the coracoid bone; it has only two in the crocodile, the scapula, and the coracoid, the true clavicle being wanting; the three bones reappear in the lizards; there are two in the tortoise, the scapula and coracoid, or perhaps three, for there are traces of a clavicle; there are certainly four in the frog, the clavicle, coracoid, and an omoplate, divided into two pieces; and, what is remarkable, it is precisely of these two pieces of the omoplate that the shoulder of fishes is composed. The *sternum* in the crocodile is a single bone; in the tortoise it is always composed of nine pieces; it recovers in the lizard the simplicity which it exhibits in the crocodile; it has but two ossified pieces in the frog; a sort of sternum is hardly discoverable in certain fishes; in the mammals, on the contrary, it is highly developed; here we count as many as seven, eight, nine pieces, placed ordinarily on a single line; and as to birds, there are five pieces in the gallinacea; there are not more than two in ducks; its composition is again changed in pigeons, in sparrows, in birds of prey, &c. Thus the sternum not only varies from one class to another, it varies in the same class, and that in the very class of birds where, in general, unity or conformity of organization is so constant and conspicuous.

But, in reference to this question of osteological unity in vertebrate animals, there are two apparatus which have a peculiar importance: these are the *auricular* and the *hyoid* apparatus. By the auricular apparatus we here designate a chain of small bones, placed within the tympanum of the ear, and which extends from its membrane to the *fenestra ovalis*. In the mammals we count always four of these small bones, the malleus, the incus, the lenticular, and the stapes; in the birds we find but one, formed of two branches, one of which adheres to the tympanum, the other presses upon the fenestra ovalis; in like manner a single ossicle replaces, in the crocodile, the four small bones of the ear of mammals; it is a stapes still more simple than that of birds; * there is but a single ossicle in the tortoise, the lizard, the serpent; in the frog, the auricular chain might be pronounced somewhat complex did it not remain in great part cartilaginous; lastly, in the salamanders, the sirens, the protei, the last auditory ossicle itself, the stapes, is reduced to a simple cartilaginous plate. From this to the complex apparatus of the mammals is certainly a wide interval, and when we thus follow step by step this successive simplification, when we arrive thus at that final reduction of the whole apparatus to a simple cartilaginous plate, we recognize the full force of M. Cuvier's opinion that this apparatus, after having disappeared in the aerial vertebrates, is not all at once restored in the class of fishes, there to form the *opercula*, and that these opercula are consequently a special apparatus appropriate to this latter class.

The facts which concern the inverse progression of the *hyoid* apparatus, that is to say, its gradual development from the mammals to fishes, are still more important, and, in relation to theories of the skeleton, more decisive. In man this apparatus is composed of five parts: of a body, of two branches or anterior processes which suspend the hyoid to the cranium, and of two posterior ones which suspend the larynx to the hyoid. Even in the mammals the apparatus undergoes great modifications, depending on the form of its body, the soldering of this to the posterior branches more or less promptly, the number, shape, and proportion of the anterior branches. In birds these anterior branches are no longer attached to the cranium, but simply pass around and behind it; to the back part of the body of the bone is soldered a single slender bone, on which rests the larynx, and which, in itself alone, represents the two posterior branches; in front is another bone which penetrates into the tongue, being the lingual bone.

The *hyoid* of the crocodile is one of the most simple. Its body consists of a

* We might, in truth, give the name of *malleus* to that branch which in birds and crocodiles is inserted in the membrane of the tympanum, but still there would be neither *incus* nor lenticular ossicle.

thick and broad cartilaginous plate, without any very distinct vestige of the posterior branches, and a single ossified piece, representing the anterior branches. The hyoid of lizards is much more complex, and that of the tortoise even more so than that of the lizard. * * * But it is in the batrachians, chiefly, that the hyoid acquires importance, and thus leads by degrees to the hyoid of fishes, so rich and complicated. To explain this richness of the hyoid apparatus in fish, recourse had been had to a pretended intercalation which has taken place of pieces borrowed at once from the sternum, the larynx, and the ribs. It will be perceived that the metamorphosis of the frog, which, in its first period, respires by bronchiæ or gills, like the fish, which at a later period respires by lungs, like the land animals, and the bronchial apparatus of which changes by degrees, and visibly, into a true hyoid, should have settled all difficulty in this respect. M. Cuvier, therefore, made this singular metamorphosis a detailed study; he followed it in its whole progress; he saw the branchiæ and branchial arches successively fall; he saw the proper hyoid of the adult frog take shape proportionably; and at no time, even at that of the greatest complication, when the branchial arches and the branchiæ existed, neither did the sternum nor the larynx take, nor could they take, any part in this whole composition; for the branchial apparatus still very distinctly exists, with all its parts, which are clearly to be seen, as well as the larynx, with its dependent lungs, and the sternum, with the bones which rest against it. The hyoid of the salamander is metamorphosed like that of the frog, and the branchial apparatus, in the same way, still very distinctly subsists, although the larynx, the lungs, and the sternum, are also present; and all this acquires new force from what is observed so plainly in the axolotl, the proteus, the siren, animals in which the branchial apparatus exists simultaneously, and in a constant manner, with the larynx, the tracheal artery, &c. The branchial apparatus is, therefore, only a more complex hyoidian apparatus, and not one resulting from the combination of parts foreign to it, and derived from neighboring organs.

Each apparatus has, therefore, its proper constitution; it has its marked increments and decrements; its parts change from one class to another in form, in number, in complexity; and it is these very changes which determine the organic characters of classes, of orders, of genera, of species. What, then, must be understood by *unity*, or, to speak more exactly, by *conformity of organization*, by conformity of plan, in the vertebrate animals, at least in what regards their osseous system, if not an assemblage of graduated analogies, more constant in the essential apparatus, more variable in the accessory, and of which the limit cannot be given, for each apparatus, except by the direct and consecutive study of all the modifications of that apparatus, in all the classes? Now this consecutive study of an apparatus through all the classes, and of all the graduated modifications which it undergoes from one class to another, is precisely what constitutes the most distinctive feature of Cuvier's method, and the point which ought perhaps most to fix the attention of right-minded inquirers; for it is on the rigorous and special adaptation of the method to its object, that depends the exactness of the results. Now, what is here the question? Of following, of recognizing an apparatus through all its metamorphoses of number, of form, of complication of parts. And is it not plain that to lose sight of a single intermediate metamorphosis would suffice to render impossible all recognition of those which follow, would be to lose the thread which connects one with the other, nay, to lose the apparatus itself? The principle of successive and graduated modifications, employed by M. Cuvier, is one, then, of the most fruitful as well as most ingenious means of investigation with which he has enriched science, and the only one which can give, in a sure and precise manner, both the determination of each apparatus, and the limit of its analogies or its dissimilarities in each class.

VI.—RESEARCHES ON FOSSIL BONES.*

The first object of this work is the comparison of fossil with living species; and this comparison bears principally on two classes of vertebrate animals: *mammals and reptiles.* The author commences this comparative history of the species of the ancient and the actual world, with the pachydermata; he continues it with the ruminants, the carnivora, the rodentia, the edentata, and the cetacea; and concludes with the reptiles. The fundamental result of the whole work is, that no fossil species, or scarcely any, at least in the two classes of mammifers and reptiles, has its analogue among living species. It has been already said that to arrive at this result, it was necessary that the author should review all the fossil species, that he should compare them all, and one by one, with all the living species, and it has been shown to what precise, rigorous, and almost infallible laws he has subjected the admirable art of reconstructing all these lost species from their scattered remains. I shall apply myself here chiefly to another point: that of the particular and detailed comparison of fossil with existing species.

I begin, as M. Cuvier has done, with the pachydermata. This family, natural as it is, was almost entirely overlooked by Linnæus. Storr, who had clearer conceptions of it, characterizes it by this definition: *mammals with hoofs with more than two toes.* But without speaking of the *anoplotherium*, a fossil species which has only two toes, and which is not the less a true pachyderm, it is evident, from a consideration of the whole structure, that the *solipeds* should be united to the ordinary pachydermata. The number of the toes, therefore, can no more be taken into consideration in this family than in the others. Cuvier defines it: *animals with hoofs, non-ruminants.* Before him, the order or family of pachydermata comprised but five genera: the elephant, the rhinoceros, the hippopotamus, the tapir, and the hog. M. Cuvier introduced into it two other genera, the horse and the daman. * * * Considered in their relations to the revolutions of the globe, the fossil pachydermata form two groups: the pachydermata of loose and alluvial formations, and those of the plaster quarries, so abundantly accumulated in the environs of Paris. To the former pertain the fossil elephant, mastodon, hippopotamus, rhinoceros, horse, &c.; to the second, the palæotherium, the anoplotherium, the lophiodon, the anthracotherium, the chæropotamus, the adapis. All the species of the first of these two groups are now lost; but the greater part of its genera subsists. Not so with the second, in which both genera and species are equally extinct. * * * Beginning with the pachydermata of loose and alluvial formations, the first of these animals which M. Cuvier studied under this new point of view, of the comparison of fossil with living species, was the *elephant.*

Till then, almost everything relative to this singular quadruped was alike unknown. It was not known, at least with any precision, whether there was only a single species of elephant or several species, nor, with stronger reason, whether the fossil bones might be referred or not to the living species. The first truly specific distinction of these animals, that which is founded on the structure of their molar teeth, only goes back to Camper. Blumenbach had also seen this difference in the form and number of the laminæ of the molar teeth, which distinguishes the elephant of Africa from that of the Indies; but so far this was all, and it is to Cuvier that we owe the determination of all the other differences, derived from the bones of the skull, from those of the face, and of the

* The first edition of this great work, published in 1812, was scarcely more than the reunion of the memoirs, inserted successively by the author, in the *Annales du Muséum d'histoire naturelle.* The second edition appeared from 1812 to 1824. It is not only enriched with a great number of new facts, but the entire work is recast throughout, and arranged in more methodical order. The third edition is of 1828, and is distinguished from the second by certain additions to the *Introduction*, which latter has been often printed separately, and has become celebrated under the title of *Discours sur les révolutions de la surface du globe.*

entire skeleton. He shows that it is from these bones, especially those of the skull, as well as from their teeth, ears, &c., that the two living species, that of Africa and that of India, are distinguished from each other; thus the species of India has the head long, the forehead flat, or even concave, while that of Africa has the head round and forehead convex; the former has the laminæ of its molar teeth in the form of wavy or festooned ribands; in the latter these laminæ are lozenge-shaped; this last has larger ears and tusks, &c. As to the fossil species or *mammoth* of Russia, it is essentially distinguished from the two living species, and in particular from the species of India, to which, however, it is most nearly allied, by its molars, the laminæ of which are closer and straighter, by the alveoli of its tusks, which are longer, by its lower jaw, which is more obtuse, &c.; finally, the entire individual, discovered in 1806, on the coast of Siberia, has taught us that it had two sorts of hair, a reddish, coarse, and tufted wool, and long, black and stiff hairs.* To this it may be added that the bones of this last species are never found but in a fossil state, and that, on the contrary, the bones of the other two species are never found in that state. The fossil is, therefore, a lost species. Further, its bones, dispersed through almost all the countries of the world, are always found in the same strata as those of the mastodon, the rhinoceros, and the hippopotamus. All these species, then, are of the same epoch, and are all alike extinct. Among them the species which approaches nearest to the elephant is the mastodon; it was of the same general form, had feet of the same structure, a proboscis, and long tusks; yet these were essential differences, as well from these tusks being curved in the opposite direction to those of the elephant as from the circumstance that the molar teeth, instead of being formed of transverse laminæ, presented a simple corona well furnished with tubercular or mamillated prominences. The mastodon is the largest of fossil animals, yet Daubenton fell into the error of referring a part of its bones to the elephant and another part to the hippopotamus. W. Hunter pointed out that the mastodon differs sensibly from both those animals. Camper showed that it more closely approximated to the first than to the second. Finally, M. Cuvier has completely demonstrated that the mastodon was neither elephant nor hippopotamus, and that, though nearer to the former, it is essentially distinguished from it by its jaw-teeth; and that not only as regards species but genus. That genus itself already comprises as many as six species, of which the most celebrated is the great mastodon or *animal of the Ohio,* which has left its bones only in North America. Another species, long confounded with the latter, has been distinguished from it by M. Cuvier; this was the *mastodon with narrow teeth,* the bones of which are found in both continents. Of four other species, two pertained to America and two to Europe. The genus of elephants showed us but one species destroyed; the entire genus of mastodons has perished.

The genus *hippopotamus,* which, so far, is known to possess but one living species, numbers already several fossil species. The first or largest, and the only one regarding which some imperfect notions were entertained before M. Cuvier, differed nearly as much from the living species as the fossil elephant from living elephants. A second, the small fossil hippopotamus, differed much more. The others are as yet little known. The bones of the hippopotamus accompany, in many places, those of elephants and mastodons, but they are much more rare; the upper Val d'Arno is hitherto the only site where they have been found in any abundance.

After the genus *hippopotamus* comes that of the *rhinoceros.* Here, as with the rest, the osteology and the distinction of living species are always the two points of comparison to which the whole study of fossil bones and species refers

* The bones which were shown at Paris, towards the commencement of the 17th century, as being the bones of King *Teutobochus*, and which were the subject of a long controversy between Habicot and Riolan, are now at the museum. They are not those of an elephant, as Riolan thought, but of the mastodon.

itself. We know at present four living species of the rhinoceros. The first is the *rhinoceros bicornis*, of the Cape, which has molars, but no incisors; the second is the *rhinoceros unicornis*, of the Indies, which has incisors separated from the molars by a vacant space; the third, the *rhinoceros of Sumatra*, appears to form, as it were, an intermediate species between the two preceding, for it has two horns like the rhinoceros of the Cape, and incisors like that of India. The fourth is the *rhinoceros unicornis of Java*. Thus, there are four living species; two having one horn, two having a second horn. The number of fossil species is not clearly established. The most celebrated, that whose nostrils are separated by a bony partition, is found in Siberia, and in different parts of Germany. The second, that whose nostrils are not separated by a bone, has been thus far found only in Italy. Both species had two horns, and both appear to have wanted incisors. As to other species, to the number of two or three, they are as yet indicated only by a few fragments. It was to the species with partitioned nostrils that the entire rhinoceros, withdrawn in 1770 from the ice on the banks of the Wilhouï, belonged. This rhinoceros was covered with a thick coat of hair, much like the fossil elephant, which seems to prove that both could live at the north. "Thus," says M. Cuvier, "the cold countries which surround the pole must have had, at the epoch which preceded the last revolution of the globe, the great pachydermata, as they have now the great ruminants; the musk-ox, the bison, the elk, the Canadian stag, the reindeer, the great carnivora, the white bear, the morse, and so many large seals."

We know, as yet, only the lower jaw of the *elasmotherium*, a fossil genus of Siberia, discovered by M. Fischer, a genus entirely lost, like the mastodon, and which, to judge from this jaw, must, in form and stature, have approximated to the rhinoceros. The genus *equus* has left a great number of its bones, mingled with those of the elephant and rhinoceros; but there has been thus far no osteological difference observed between these fossil species and the living species; and what is not less singular is, that none has been found, at least none sufficiently fixed and decided to be really characteristic, between the different living species of this genus: the horse, the ass, the zebra, the quagga, &c. The bones of the *hog* have not yet been discovered in any strata so old as those of the fossil elephant, horse, and rhinoceros. M. Cuvier gives, however, the osteology of this genus, for his work has two objects equally important: the determination of fossil species, and the elements and means of this determination; that is to say, the general laws of comparative osteology. Thus, it is only to establish this great assemblage of osteological facts and laws that he gives the description of the *daman*, for neither have the remains of this animal been found among fossil bones. The daman, a small animal of Africa and Arabia, passed for a rodent. M. Cuvier shows that it is a true pachyderm, and the one, indeed, which of all others, approaches nearest to the rhinoceros. A genus not less singular than that of the daman, and the osteology of which was not less unknown, is that of the *tapirs*. These number at present three living species: two of America and one of the Indies; and M. Cuvier describes several fossil animals related to the tapirs.*

The elephant, the rhinoceros, the hippopotamus, the mastodon, &c., as here described, were the pachydermata of the alluvial formations. We see that all their species are distinct from the living species; that they are all lost, and that they were all destroyed at the same epoch and by the same catastrophe; for their bones are found in the same deposits, everywhere united and mingled together. The fossil pachydermata which we are about to consider are all of another epoch, and one much more remote; and nearly all of these were discovered by M. Cuvier, in those plaster-quarries of Paris, which have thence become so celebra-

* As regards his *gigantic tapir*, we now know that it is a very different animal from the tapirs. This great tapir of M. Cuvier is the *Deinotherium giganteum*, the head of which has been made known to us by MM. de Klipstein and Kaup. M. Cuvier scarcely knew any part of it but the molar teeth.

ted; they are the *palæotherium*, the *anoplotherium*, the *chæropotamus*, the *adapis*. The bones of all these genera — most of which include several species — were mingled and confounded together. It was necessary to begin by separating them; it was necessary, then, to assign each bone to its species, and finally to reconstruct the entire skeleton from each of them; and it was here that the method devised by the author for this reconstruction was exhibited in all its efficacy.

In regard to fossil species, the teeth are always the first part to be studied, and the most important, for it is from the teeth that it must be determined whether the animal was carnivorous or herbivorous, and even, in some cases, to what particular order of such animals it pertained. M. Cuvier then having re-established the complete series of teeth which were found to be most common among those which he had collected, soon saw that they proceeded from two different species, of which one was provided with prominent canine teeth, and which the other wanted. The restitution of the teeth thus gave two species of pachydermata: the one with prominent canines, being the *palæotherium;* the other, without them, or with a continuous series of teeth, the *anoplotherium.* Further, this restitution of itself showed, in each of these species, the type of a new genus; two genera related to the tapir and rhinoceros, but two genera entirely lost; for no living pachyderm reproduces, even generically, their dental system. And such, on the other hand, was the rigor of the zoological laws followed by the author, that the teeth having given him two distinct genera, it could not be doubted that all the other parts of the skeleton, the head, trunk, feet, all mingled indiscriminately with one another and with these teeth, would be also of two different genera. He at once foresaw, therefore, for each of these genera, a head, a trunk, feet of a particular form, as he had found for them an appropriate dental system; and he was not long in finding all that he had foreseen.

The teeth being re-established, the restitution of the heads claimed his attention, and it was soon evident that these also were of two genera. Next to the teeth and head, the feet are the most characteristic part of the skeleton, and their restitution gave likewise two genera. It remained, therefore, only to refer each foot to its head, and each head to its dental system. Now, the restitution of the hind feet had shown them to be of two kinds, some with three toes, others only two; and the restitution of the fore feet had yielded the same result. Availing himself, by turns, of the general analogy of the species which he reproduced with the nearest living species, and of the particular relations of proportion and size of the different parts in question, one with another, M. Cuvier first united the hind feet with two toes to the fore feet with two, and repeated the process with those having three; and always guided by the same analogy, the same relations, he united the former with the dental system which was destitute of prominent canines, and the latter with the dental system which had them. He thus united in succession, for each genus, all the bones of the head, the trunk, the extremities; he reproduced, finally, the entire skeleton, and scarcely was this great labor terminated when, by a singular hazard, a nearly complete skeleton of one of them, found at Pantin, came to confirm all the results which had been obtained. In this skeleton, so fortunately discovered, all the bones were united together as M. Cuvier had united them; nature having acted no otherwise than the admirable laws discerned by him and his own wonderful sagacity had acted.

A first species of each genus being in this manner reconstructed, their number was not slow in augmenting. M. Cuvier soon counted five species of *anoplotheriums*, and not less than 11 or 12 *palæotheriums*. All the former are from the environs of Paris; the most common was of the size of the ass; another of that of the hog; a third, of that of the gazelle; a fourth, of that of the hare; a fifth was still smaller. Among the palæotheriums there were, at Paris alone, seven species; one the size of the horse, one of the tapir, one of the sheep, one of the hare, &c; another species discovered near Orleans, nearly equalled in size the rhinoceros.

The palæotherium which, at Paris, always accompanies the anoplotherium, is accompanied almost everywhere else by another genus not less remarkable, and which, by a singular exception, is absolutely wanting at Paris, the *lophiodon*. This new genus, also approximated greatly to the tapirs, like the palæotherium and anoplotherium; is, like these last, entirely lost, and like them, already rich in species. M. Cuvier has made known a dozen, all of France. The genus *chœropotamus* and the genus *adapis* number each but one species. The genus *anthracotherium* numbers two, one of which approached the rhinoceros in size. The two former genera are of the environs of Paris; the third was first found near Savona, and afterwards in Alsace and Velay.

With these numerous pachydermata, first among terrestrial mammals to occupy the earth, M. Cuvier collected the remains of *carnivora* of the genus of the dog, the genet, the raccoon, &c.; a bat of the genus vespertilio; a species of didelphys; two rodents, one pertaining to the dormouse, the other to the squirrel; six species of birds, relics of the crocodile, the *trionyx*, the *emys*, and certain species of fresh-water fish. But to restrict ourselves to the pachydermata which form, beyond comparison, the most important part of this antique animal colonization of the globe, we have nearly 40 species and five genera totally lost; and what is not less noticeable, none of their species are found mingled with those of the elephant and the mastodon. The two classes of animals belonged therefore to two essentially distinct ages.

To the pachydermata succeeded, in M. Cuvier's investigations, the *ruminants*. It is only in the alluvial formations that the bones of these abound, and here two genera especially show themselves in great number: the stag and the ox. * * * It is in the caverns of Germany, England, France, &c., that the fossil remains of the *carnivora* especially abound. After having extricated the living species of these animals from the confusion which had thus far attended their determination, M. Cuvier proceeds to describe the fossil species—four species of bears: that of the caves, the most numerous of all, the arctoid bear, the intermediate bear, the bear with flattened teeth; a hyena, almost as abundant as that of the bears, which is most so; two tigers, a wolf, a mouffet, two weasels, a glutton, &c. The fossil *rodentia* are not numerous. The great beds of the loose formations have yielded hitherto but one large species of the beaver, called by M. Fischer the *trogontherium*. The bone breccia gives two species of the *lagomys*, two of the rabbit, of the field mouse, the rat, &c.

The order of the *edentata* has two fossil, but gigantic species: the *megalonyx*, of the size of the largest ox, and the *megatherium*, of that of the largest rhinoceros. These two enormous species are from America. An unguiculate phalanx, found in a canton of the Palatinate, not far from the Rhine, indicates a third species related to the *pangolin*, and quite as gigantic as the two others.

So much for the inhabitants of the land formations. The *cetacea* all pertain to strata essentially marine. Here, with the cetacea, occur the amphibious mammals, the seal and the walruss. A first group of these marine mammals, whose osteology and living species themselves were then so little known, preceded all the terrestrial mammals. Their remains disclosed to M. Cuvier bones of the dolphin, the lamantin or manatee, and the walruss. A second group had succeeded the *palæotheriums;* and among them M. Cuvier recognized a dolphin, a whale, and an entire genus wholly lost, the *ziphius*, related to the sperm whales and *hyperoodons*.

We come now to the *reptiles*. M. Cuvier considers in succession the crocodiles, tortoises, lizards, batrachians, and concludes with the extraordinary family of the *ichthyosaurus* and the *plesiosaurus*. The fossil crocodiles are very numerous, M. Cuvier having described as many as fifteen species. The fossil tortoises are even more numerous still, from sixteen to seventeen species having been already discriminated; among them, several of the *trionyx*, several of the *emys*, or the tortoise of fresh water, several of the *chelonia*, or tortoises of the sea, and some

terrestrial tortoises. The order of *batrachians* has but one fossil species: the *gigantic salamander of Œningen*, or the pretended *fossil man*—the *homo diluvii testis* of Scheuchzer. The order of reptiles which presents the most extraordinary fossil species is that of the *saurians*. In the first place, most of them were gigantic. A first species, the great saurian of Manheim — the *lacerta gigantea* of Sœmmering, the *geosaurus* of M. Cuvier — was twelve or thirteen feet in length; a second, the *mosasaurus*, the great saurian of the quarries of Maestricht, long taken for a crocodile, was more than twenty-four; and a third, truly gigantic, the *megalosaurus*, was more than seventy. Here, then, we have a lizard which surpassed the largest crocodiles, and in size even approached the whale. This, it is known, was discovered by Dr. Buckland, in the oolitic beds of Stonesfield, near Oxford. M. Cuvier further makes known some remains of the *fossil monitors* of Thuringia, of a great saurian at Honfleur, of a gigantic saurian in the quarries of Caen, &c.

The genus of *pterodactyls*, or flying lizards, though not remarkable for its size, is eminently so for its singular structure: a very short tail, a neck very long, a bird's beak, a finger of the anterior extremity prodigiously elongated, and thus elongated to support a sort of wing. There are two species of pterodactyls: one of the size of a bat, the other rather larger. It is needless to add that the genus is wholly extinct. But something still more strange in point of structure, is that presented by two other genera of saurians, both likewise extinct: the *ichthyosaurus* and *plesiosaurus;* the former uniting at once the snout of a dolphin, the teeth of a crocodile, the head and sternum of a lizard, paws of the cetacea, but to the number of four, and the vertebræ of a fish; the latter joining to these paws the head of a lizard, and a neck of such inordinate length that more than thirty vertebræ are counted therein. Both these extraordinary animals were found for the first time in England, but have since been discovered in Germany and France. The discovery of the first of these genera was due to Sir Everard Home; that of the last to Mr. Conybeare. Already four species of the ichthyosaurus are known, and five of the plesiosaurus.

These reptiles, so numerous and so varied, crocodiles, tortoises, the vast salamander, the strange or gigantic saurians, joined with crustacea, mollusks, zoophytes, fishes, marine mammals formed the first animal colonists which occupied the globe; the second were those of the epoch of the palæotherium; the third, those of the epoch of the mastodon; the fourth are those of the actual epoch. Without counting the last, there have been three distinct eras of animal life: that of the reptiles, that of the palæotheriums, that of the mastodons; and after each successive family of living beings, the sea has returned to repossess itself of the land, retreating afterwards in favor of a new order of creatures; for marine strata constantly succeed to the terrestrial strata, and animals which have lived in the sea constantly succeed to animals which have lived on dry land.

Such is the assemblage of fossil species, reconstructed by M. Cuvier. We have seen the precise laws on which this reconstruction is founded. The highest of these laws is the principle of the *correlation of forms;* a principle by means of which we are enabled, to a certain point, to determine from each part all the others; for each part has a necessary relation to all the others, and all to each. Thus, and to cite again a new example of this great law of organic correlations, the form of the teeth, and even, in certain cases, the form of a single tooth, gives that of the condyle of the jaw; the form of this condyle gives that of the glenoid cavity which receives it; this condyle, this cavity, give the zygomatic arch, the temporal foss, in which the muscles are attached which move the jaw. The form of all these parts, that is to say, the mode of manducation, gives the stomach, the intestines, that is to say, the mode of digestion; this again gives the mode of prehension, or the form of the feet; for if the animal is herbivorous, it has no need of the feet except to support its body, it will suffice for it to have hoofs; and if it is carnivorous, it will necessarily require, on the contrary, divided feet, that is to say digits for seizing its prey and tearing it.

By proceeding thus from one part to another, we apprehend the relations which bind each of them, first to that which follows, and then nearer and nearer to all the others, even to the most remote, without the chain of relations being ever at any part broken or detached. From each part, and even in appearance the most insignificant part, we may therefore infer all the others, and the entire animal itself.

For example: that claw of the pangolin, found in the Palatinate, huge as it is, demonstrates of itself a lost species; and from this claw alone we might infer, as M. Cuvier well says, all the revolutions of the globe. In effect, this claw necessarily gives us a toe, and this toe a limb, and this limb a trunk, and this trunk a cranium, a head, proportionate all with one another; that is to say a gigantic pangolin, consequently a lost species, consequently revolutions, subversions experienced by the earth, and which have destroyed that species. But I confine myself here to recalling those great laws on which I have dwelt at more length elsewhere, and which astonish us less, perhaps, by their extent than by the amount of evidence which they carry with them.

MEMOIR OF OERSTED.

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[*Translated for the Smithsonian Institution by C. A. Alexander.*]

Science, like nature, is one; the frontiers of states, the limits of populations, arrest not its propagation. In all civilized countries men calculate with the same figures, measure with the same instruments, avail themselves of the same classifications. Scientific bodies animated by a common spirit collect, by analogous means, the results of the general labor; and all these associations, to give a higher sanction to their mutual collaboration, have desired that the most eminent and celebrated of the savants of foreign countries should constitute a part of their official list.

Among the illustrious persons on whom the Academy has successively conferred the title, so justly coveted, of one of its eight foreign associates, few have better justified the distinction than he to whom we owe the knowledge that the mariner's compass and the lightning conductor present only different effects of identically the same physical agent.

Jean-Christian Oersted† was born August 14, 1777, at Rudkjöbing, in the island of Langeland, one of the smallest of the archipelago of Denmark. His father exercised the profession of apothecary, and, although the town of Rudkjöbing then counted less than 1,000 inhabitants, he had full occupation. For fear that the young Christian should not be properly looked after in the paternal dwelling, he was sent every day to the house of a wig-maker, whose wife enjoyed the confidence of his parents. A brother, one year younger, who became in after life the celebrated jurisconsult André Sandöe Oersted, accompanied him thither the following year. The wig-maker and his wife formed a warm attachment for the two brothers. The wife taught them to read; the husband instructed them in German, which was his mother tongue. The pupils made rapid progress, owing, perhaps, in reality more to a happy natural aptitude than to any talent in the teachers, but which sufficed to induce many other families to send their own children likewise to this improvised school where knowledge was imparted so quickly and so well. The wig-maker, transformed into schoolmaster, daily read to his pupils some pages of a German Bible, which was thus perused from beginning to end, and afterwards, in great part, read over anew. It was the daily task of the young Christian to translate word by word into Danish what had been read in German, and this exercise so far profited him that at the age of seven years he often embarrassed by his citations those who sought to put his sagacity to the test; whence the gossips of the vicinage used to say of him, *This child will not live; he has too much smartness!*

* Read at the annual public sitting of the Academy, December 29, 1862.

† I write the name of Oersted as it has always been written in the publications of the Academy. In this the German orthography has been followed, while it would perhaps have been preferable to conform to the Danish orthography, in which the name is written *Orsted*, or without the majuscule *Örsted*. In Denmark it is pronounced *Eursted*, which is also the German pronunciation of the word *Oersted*, whence we are wrong in habitually pronouncing it as if it were written *Ersted*.

The wig-maker further taught him addition and subtraction; it was all he himself knew of arithmetic; but with a slight help from others, and a book found at his father's, the child was not slow in learning the rest as far as the rule of three, inclusive; no equivocal proof of unusual precocity of intellect. An extraordinary memory was early remarked in him, and was retained till death, equally with all the other happy endowments which he had received from nature.

When Christian had reached the age of 12, he and his brother, who was then 11, entered as apprentices the pharmacy of their father, whereby their secret wishes were at first contravened, for both had conceived the project of devoting themselves to the study of theology. The elder of the two, however, soon began to acquire a taste for pharmaceutical operations, and labored zealously in the paternal laboratory, reading at the same time all the books of chemistry and natural history which fell into his hands. Thus early was developed the inclination which led him to the study of nature. A student in theology daily devoted some hours to the instruction of the brothers in Greek and Latin. The elder applied himself moreover to the acquisition of the French, the younger to that of the English language. From this period the former evinced a decided taste for poetry, a taste which adhered to him all his life. He translated about this time several odes of Horace and a part of the *Henriade* into Danish.

These rather precarious means of instruction still bore happy fruits. In the spring of the year 1794, the brothers, aged respectively 17 and 16, were qualified to proceed to Copenhagen, where, after but a few months' preparation by a skillful master, who perfected them in the study of the ancient languages, they sustained with much honor an examination at their exit from the academy. Some two years afterwards Christian, who had in the mean time earned testimonials of distinction on all hands, bore off an academic prize for his reply to a question "On the shades to be observed in the choice of expressions, according as one writes in prose or in verse." Finally, during the autumn of 1799, he obtained the degree of doctor of philosophy upon the presentation of a thesis in metaphysics, *(de forma metaphysices elementaris naturæ externæ.)*

In the year last named, and those immediately following, he published divers short dissertations and critical analyses, which were generally inserted in the periodical collections. He thus evinced in turn the tendency of his mind to literature, to poetry, and to philosophy. These formed, indeed, only an accessory occupation; but, apart from his natural predisposition, favorable circumstances rendered these momentary efforts of singular advantage in the development of his faculties. His brother, with whom he always lived in the most cordial intimacy, had chiefly devoted himself to the study of philosophy, and the habit, which was maintained during life, of a daily interchange of ideas, led our physicist to a profitable participation in the same pursuit. Having become familiar with the writings of Kant, Fichte, Schelling, he caught sight of a great general law of unity in the physical world, which continued always to be one of the habitual subjects of his meditation. Struck at the same time with the beauty of natural laws, he became sensible of something profoundly poetic in nature, on which his innate taste for poetry seized with avidity.

His first essays, which had fixed the attention of the citizens of Copenhagen, placed him on terms of friendly intimacy with most of his young cotemporaries who were rising into distinction, particularly with Oelenschläger, who, as a poet, achieved some years afterwards so brilliant and well-merited a reputation. This attractive intercourse impelled him to the study of belles-lettres. To no important production of Danish or German literature, or of the elder French literature, was he a stranger. His admirable memory was garnished with the choicest passages, which, even at an advanced age, he was wont to cite with singular appositeness. Nor did he fail sometimes to exercise his own poetic powers, and, in the eyes of persons competent to judge of Danish verse, an *Ode to the French*, which he composed about this time, appeared to give indications of genuine talent. A

happy concurrence of circumstances brought Oersted also into intercourse with Steffens, and the two brothers Mynster, with whom he long continued to maintain philosophical and even theological discussions, which, whatever their vivacity, were never permitted to interfere with the claims of a reciprocal friendship.

The rectitude of his judgment always prevented these accessory exercises of thought from impairing the progress of his scientific studies; but they did not a little contribute to draw general attention to him; a kindly attention which greatly facilitated the development of his subsequent career.

Of that career positive science was always the basis, and his success was rapid. At his examination in pharmacy, May 20, 1797, he astonished his judges by the extent of his knowledge, and one of them, on going away, having met with Professor Manthey, proprietor of the pharmacy in which Oersted had labored, addressed him in these words: "What a candidate is this you have sent us; he knows more than all of us together!" The following year Oersted obtained a new prize from the Academy; this time on a question of medicine. In 1800 Professor Manthey, being about to travel abroad, devolved on him the direction of his pharmacy, and nominated him to supply his place, during absence, in the lecture-room of the Academy of Surgery. The same year Oersted was received as adjunct of the faculty of medicine.

At this epoch he occupied himself very actively with chemistry. The researches of Wintrel on the simple galvanic chain had already led to the conception of an electro-chemical theory, and Ritter had inferred, from the ordinary chemical and electrical facts, the identity of the forces which produce them. The labors of Berthollet on the laws of affinities had also introduced new general views on chemical forces. Herein lay the subjects of Oersted's investigations during the years 1799 and 1800. Earlier studies had prepared him for these general views, and efforts to surmount certain lines of demarcation established in science by distinctions too decisive, had even directly revealed to him some of them. An analysis of the chemical philosophy of Fourcroy, read by Oersted in 1799 to the Scandinavian society, and printed the following year in its bulletin, is unfortunately the sole trace which remains for the public of these first essays. We find there the alkalis and earths already ranged in a single series, which, commencing with the most energetic alkalis, terminates with a body rather acid than alkaline, silicium preceded by aluminium.

But, in 1800, the discovery of the electric pile by Volta threw all the chemists into commotion. Throughout Europe there was a desire to witness its effects. Everywhere were constructed similar piles or columns formed of pairs composed each of a disk of copper and a disk of zinc, pairs superposed on one another and separated by a piece of moistened cloth. Soon, every one, in the modish as in the learned world, knew by experience the strange shocks and sensations felt in the wrists, in the elbows, when in each hand is held a metallic wire terminating at one of the two opposite poles of the pile, and one is thus placed in the course of the electric current to which the pile gives rise. Oersted was not among the last to make experiments with this wonderful instrument. Having applied it especially to the decomposition of divers saline solutions, he gave expression to this first law, that the quantities of alkalis and acids set at liberty in a solution, by the action of the pile, are in proportion to their respective capacities of saturation. Here, then, was a step in the career in which he was destined one day to immortalize himself.

Oersted was now 23 years of age; the time had come for him to travel, as, in their youth, the German and Scandinavian savants almost always do. He set out in 1801, and his absence extended to two and a half years. Everywhere he found with the learned a reception which surpassed the hopes of his friends. His natural animation, joined to a candid and unaffected self-reliance, stood him in better stead than the strongest letters of recommendation. His countenance seemed to announce a certain timidity, but no sooner did any subject awaken in

him a special interest, such as a point of science to discuss or error to combat, than he was seen to put forth a boldness, a force of intellect, an eloquence which would scarcely have been suspected from his modest exterior and reserved demeanor.

He first traversed a great part of Germany, passed six months at Berlin, and sojourned for some time at Friburg, Jena, and Munich. A new life then animated that country. Poets and philosophers of eminence had there given to the human mind an unexpected impulse. This movement bore especially on the natural sciences, and that assemblage of somewhat vague ideas which was called the philosophy of nature was in process of development. Oersted, with his philosophic and poetic views on the unity and the beauty of nature, was sufficiently disposed to lend attention to the new German doctrines, and he himself avows their influence by saying, in the preface of one of his works, published in 1813: "The philosophy of nature, which has been cultivated within 20 years in Germany, might also assert its claim to some of the views which we are about to offer." Yet he never allowed himself to be turned aside from the severe and positive study of facts and of experiment.

He enjoyed constant conversations with Klaproth, Hermstadt, Paul Erman, Trommsdorff, with Kielmeyer, the master and friend of Cuvier, with the celebrated Werner, at Friburg, and with the profound mineralogist and crystallographer Weiss. He met also Fichte, Schelling, Franz Baader, Schleiermacher, Tieck, and the two Schlegels. But he associated himself more particularly with the ingenious physicist Ritter, already celebrated for his experiments in galvanism, in which he had established, among other things, that a constant development of electricity accompanies the phenomena of life. They executed in common a series of remarkable experiments, and Oersted conceived from that time a high opinion of the scientific capacity of his collaborator, which frequently appears in his writings, and particularly in the following passage of the preface of his *Researches on the Identity of Chemical and Electrical Forces*, published in 1813: "Ritter may, in this respect, be regarded as a creator.* His grand conceptions, and his labors encountered with a zeal which obstacles and sacrifices were incapable of subduing, have shed light on almost all parts of the science." Oersted often expressed the opinion that, with more of sequence in his labors, Ritter would have discovered the electric pile before Volta. Unfortunately Ritter joined with a very ingenious mind great eccentricity, which crippled his pursuits and abridged his days.

After sojourning some time at Munich with Ritter, Oersted published at Ratisbon, in 1803, a small work entitled *Materials for a Chemistry of the XIXth Century*, in which occur highly interesting views respecting the new horizons opened to chemistry by the discovery of the Voltaic pile. Before parting with Ritter, who remained at Munich, Oersted had rendered him services which could only have been inspired by a warm and sympathizing friendship. He proceeded afterwards to Paris and passed there 15 months in habitual intercourse with Cuvier, Haüy, Vauquelin, Charles, Berthollet, Biot, Guiton-Morveau, Thenard; assiduously following the courses of the distinguished professors and sometimes making communications, on his own experiments, to the Philomathic Society.

During his stay at Paris he translated into French a German memoir of Ritter on the *pile à charger*, or secondary pile, (*Ladung's Säule*). This translation, accompanied by notes on the experiments made by himself, was presented to the first class of the Institute and printed in the *Journal de Physique*, number for *Brumaire, an* XII, (1803.) Ritter, who had co-operated in the translation by an uninterrupted correspondence with Oersted, was fully satisfied with it, and even avowed that he comprehended himself in the French version better than in his own original German text. He died soon afterwards, and Oersted, independ-

* See *Researches sur l'Indentité des Forces Chimiques et Électriques*, by M. Oersted, translated from the German by M. Marcel de Serres, 1813, p. 10.

ently of his own original ideas, remained the representative and, in some sort, the heir of those of Ritter, of whom he had been the last collaborator and interpreter.

Some prepossessions, whatever their origin, perhaps the fear of being received with a certain superciliousness, had led Oersted to pass almost the whole time of his sojourn in Paris without going to present to the celebrated Fourcroy, professor of chemistry at the Polytechnic School, a letter of professor Manthey, of Copenhagen. He decided at last to do so at the instance of the chargé d'affaires of Denmark. The elegance, the clearness, the authority with which Fourcroy discharged the functions of professor, gave him great ascendency over his pupils; but, out of the chair, he did not always sufficiently divest himself of the magisterial dignity. He congratulated the young and modest Oersted on having come to Paris and having acquired a knowledge of so many remarkable men, superior beyond doubt to all the chemists of the north. "I must acknowledge," replied Oersted, "that you possess at Paris more dexterity than exists elsewhere in chemical manipulations; but there is scarcely to be found in the north a single chemist who cannot read in the original the *Système des connaissances chimiques* of M. de Fourcroy, which few French chemists could do for works written in the Scandinavian languages." To the question, if he had seen the Polytechnic School, Oersted replied of course affirmatively, and Fourcroy having made him duly sensible that this school gave to Paris a great superiority over Denmark, Oersted rejoined, with perhaps too ingenuous a confidence: "I admit that my country wants much which is needed for the fruitful development of chemistry, but I do not despair of contributing hereafter to establish there something not unlike the Polytechnic School." Upon which, Fourcroy begged him, somewhat ironically, to be sure to preserve, when he returned home, a kind recollection of the French chemists. This Oersted did not fail to do, and I shall show further on how he proved it.

In returning to Denmark, Oersted traversed Holland, and, at Harlem, made a great number of electrical experiments with the learned physicist Van Marum. At Bremen he contracted a friendship with the astronomer Olbers, and with Treviranus, celebrated for his labors in physiology and comparative anatomy, and finally re-entered his country in the month of January, 1804. On his return, the duty, at first temporary and limited to three years, of delivering lectures on physics at the University of Copenhagen was confided to him; in 1806 he was named professor extraordinary of physics in the same university. He had here the first opportunity of combining his scientific views in a systematic shape, the outline of which he preserved during his entire life, only modifying certain parts according to the progress of science.

His lectures commanded a large attendance; they bore a form which was peculiar to himself. The skillful professor usually commenced in a subdued tone, with particular considerations and explanations; frequently, indeed, with the definition of certain expressions, turning on the translation of technical words into the Danish language. Assured thenceforth of being fully understood, he followed the logical course of ideas, and warming by degrees, collected the facts into groups, and these groups into a whole still more comprehensive. The animation of the lecture, in giving more freedom to his delivery, called forth his favorite thoughts on the unity, the beauty of nature, and figures and images presented themselves which keenly interested his auditors, especially the younger portion of them, for those who had already followed other lectures were more surprised at still finding something unusual in his.

It was sometimes objected to Oersted that he saw or imagined in nature combinations much more rational than those which can be expected to occur in an assemblage of material objects; but he replied that nothing is too rational to be attributed to the supreme reason which has created everything. On such a theme it would be easy to argue a long time without coming to an understanding. It would be to plunge into the depths of those German discussions in which so

many a subtle genius has exhausted itself without exhausting the subject. But the obscurity of these depths is sometimes quite *à la mode* on the shores, always a little foggy, of the Baltic sea.

It seems certain, however, that the lectures of Oersted were well received by the youth and the public of Copenhagen, for they were always much frequented, and they secured for the professor an eminent position among his fellow-citizens. He was not long in establishing agreeable relations with persons of the highest position in the capital of Denmark, and even with the princes of the royal family.

But a part of his success might also be attributed to his lively and intellectual conversation, to the frequent articles which he put forth on various subjects, and to the works which he published at this epoch, such as his *Considerations on the history of chemistry*, his *Experiments respecting the figures produced by nodal lines on vibrating surfaces*, a subject to which Chladni had already devoted an important work; and a *Discourse on the pleasure produced by sound*, a discourse in which he developed, under a point of view peculiar to himself, the *laws of the beautiful*.

He thus continued to publish, as he had done from his youth, a multitude of memoirs and articles of more or less extent on different subjects relating to the natural sciences and to philosophy, all of which met with appreciative readers. Nevertheless, Copenhagen was not a center to which everything converged as is Paris or London. In a city of secondary importance one may keep himself informed of what is written, but the inconvenience is soon felt of not knowing what is talked about in the learned world. Oersted, who had need of direct communication with entire Europe, felt himself impelled to undertake new expeditions. He set out for Berlin May 7, 1812, where he passed three months and gave to the press, in the German language, one of his most important works, entitled "Views of the chemical laws of nature," (*Ansichten der chemischen Naturgesetze.*) In passing through Germany he visited Oken, Schweiger, and Hegel, and established friendly relations with the ingenious physicist Seebeck, who, some years afterwards, made the discovery of thermo-electricity. He then revisited Paris, where he made quite a long stay, and, about the middle of the year 1813, returned to Copenhagen, there to receive anew from his countrymen tokens of the cordial consideration which he had long before inspired.

In 1814 Oersted published, in the programme of the university, an essay on a chemical nomenclature common to all the Germano-Scandinavian languages. The names proposed were so happily appropriate to the genius of those tongues that they were generally adopted, and are still in use in all the countries of the north. In 1815 the Royal Society of Sciences of Copenhagen, having lost its excellent secretary, Bugge, Oersted was chosen to replace him, and, the same year, the King named him a chevalier of the order of Danebrog. Two years afterwards the university conferred on him the title of professor in ordinary, (*professor ordinarius*,) a title superior to that of professor extraordinary which he had borne for more than 10 years.

About this time Oersted undertook a remarkable series of experiments on the compressibility of water, and found almost exactly, though by new means of his own invention, the numbers which the celebrated English physicist Canton had obtained half a century before.

In 1818 and 1819 he undertook, with MM. Esmarch and Forschhammer, explorations in the island of Bornholm, for the purpose of examining its geological constitution with reference to the working of the coal and iron ore which are found there, and he made these investigations the subject of several publications. This was the commencement of a geological study of Denmark, established on new scientific bases. Oersted, however, was unable to prosecute this operation, which, continued by M. Forschhammer, has given to Denmark the excellent geological chart well known to this Academy.

The journeys to Bornholm did not interrupt the habitual course of Oersted's

publications on science and philosophy. Among his memoirs on physics should be particularly cited one on the trough-battery, executed in conjunction with his friend, Professor Esmarch. Another work, entitled *Principles of the New Chemistry,* which appeared at Copenhagen in 1820, had been composed for the auditors of his course, with a view to placing within their reach the doctrines taught in his numerous writings on chemistry and electricity, and particularly in his *Views of the chemical laws of nature.* First printed at Berlin, as I have said, this exposition of his favorite ideas had been translated into French by M. Marcel de Serres, and published at Paris, in 1813, with the concurrence of its author and that of our distinguished colleague, M. Chevreul, under the title of *Researches on the identity of chemical and electric forces,* a title which clearly defined its object.

This learned and ingenious work, dedicated to the author of the *Statique Chimique,* our illustrious Berthollet, was in truth the principal fruit of the labors and meditations of Oersted from his earliest youth. A citation of some passages of this admirable book will suffice to give an idea of the profound and original views which had presided over its composition: "* * * * The chemical part of the natural sciences," says Oersted, "is far from having attained the perfection which their mechanical part has reached, and cannot, like the latter' deduce from a small number of principles, already connected with one another, all the other principles; but it has been obliged to seek each particular proposition, each particular law, by means of experiments undertaken solely with that particular view. Now the greater part of these laws have hitherto so little enabled us to see the bonds which unite them, that it was necessary to be convinced, by general considerations, of the unity which exists in all the works of nature, in order not to be deceived as regards that unity.

"The actual state, in 1813, of the chemical part of the natural sciences might be compared to that of their mechanical part before Galileo, Descartes, Huyghens, and Newton had taught us to reduce the more compound movements to their most simple principles. Before these illustrious physicists, it is true, a great number of important facts were known, even some remarkable series of facts, but that great principle of unity to which science owes its present high degree of perfection had not yet been arrived at. * * * *"

Oersted saw this great principle of unity in the uniformity of the general laws of mechanics, and he found an example of the duality, which also he everywhere sought, in the two forces which concur in producing circular or curvilinear motion. To find examples of the confusion which had preceded the discovery of these forces, it is sufficient, he said, "to read what was written on the classification of motions by the celebrated Bacon, who, although a cotemporary of Galileo, still speaks of a violent and natural motion, and of so many other kinds of motions, which he knew no better how to reduce to a single principle than do the chemists at the present time know how to reduce the affinities of the alkalies, acids, earths, oxides, combustible bodies, and oxygen to one identical primitive action. * * * *

"By referring all motions to their fundamental laws, the mechanical part of the natural sciences," adds Oersted, "has been raised to that present degree of perfection which embraces all the movements of the universe as one great mechanical problem, whose solution enables us to calculate in advance an infinitude of particular phenomena. In order to prepare the chemical part of the natural sciences for a like perfection, we must endeavor to reduce all chemical actions to the primitive forces which produce them; we shall then also be in a position to calculate all the chemical properties of the primitive forces and their laws. Thus, chemistry being only occupied with these properties, this whole science will be converted into a theory of forces, to which mathematics may be applied, and it will thereby acquire perhaps new capacities, like those which have been derived from the application of mathematics to movement.

"The discoveries which have been made since the commencement of this century may so far contribute to advance chemistry towards this state of perfection that I have thought it would be useful" (it is still Oersted who speaks) "to collect here the scattered materials, in order to attempt the formation of a system. A first attempt of this kind can, doubtless, be but imperfect; but it must at last be necessary to take this first step, and I have judged it proper not to defer taking it, * * * * for the investigator of nature will make no great discovery except in so far as he shall have a certain idea which leads him to propound, so to say, his questions to nature, as well as a determinate scope for his observations. The object, therefore, of the system which we here present is chiefly to draw attention to certain important problems, and to serve as preliminary to other more perfect systems which the rapid progress of science will not fail soon to call forth. It is only by the united efforts of a great number of savants, and after some generations, that chemical science can attain that degree of perfection which, with perhaps too much boldness, we have ventured to anticipate.

"It will not be useless, at our first step in this undertaking, to cast a glance over the space which we shall have to traverse. We shall commence our researches by a general classification of all the inorganic bodies according to their chemical nature. We shall then present some considerations on the chemical actions best known, in order to prove that all the chemical phenomena which have been studied up to this time may be attributed to two forces diffused through all nature. We shall show that these forces act not only in the immediate contact between two bodies, but that they can also be transmitted, by some medium, from one to the other. This will lead us to discover, independently of electrical considerations, the chemical action which we have recognized in galvanism. By means of these successive approaches we shall be able finally to present the chemical forces in the state in which they are most free, and to render evident, at the same time, the identity of those forces with electrical forces."*

I should have abridged this long passage still more than I have done, had I not desired that it should be comprehended to what extent, according to Oersted, is to be found in the general uniformity of the laws of chemical composition that great principle of unity which, agreeably to his philosophical conceptions, exists in all nature, and, at the same time, the duality which he also sought there in the two electricities, positive and negative. "Finally," Oersted continues, "we shall endeavor, in order still better to prove the universality of the two chemical or electrical forces, to show that they also produce the *magnetic phenomena* and the principal changes in organic nature."† These lines already contained, so to say, the programme of the great discovery which he was on the point of making.

In this work, as in his earlier essays of 1799, Oersted placed aluminium in the rear of the alkaline earths, ‡ as less alkaline than all these latter, and indeed almost an acid. After aluminium came silicium, more acid than alkaline; while glass, he said, might be considered as a salt.§ It will be admitted that from thence to the theory of the silicates there was but a step; this new advance was achieved some time afterwards by Smithson Tennant; but, as every one knows, it was Berzelius, beyond all others, who developed the theory of the silicates.

The work of Oersted, which the limits prescribed to this notice do not permit me completely to analyze, contains a multiplicity of views; all equally marked by justness of thought, and more than one of which offers even at this day something of the piquancy of novelty.

In another passage, seeking to find among authors already become antique—such as Winterl, Ritter, &c.—the first rudiments of the ideas which occupied him, and which it was the object of his book to develop, Oersted added: "The

* See *Recherches sur l'identité des forces chimiques et électriques*, p. 2.
† Ibid., p. 9. ‡ Ibid., p. 57. § Ibid., p. 60.

advantage which we may attain over these predecessors of ours will be, for the greatest part, due to the profound researches of the celebrated Berthollet, and to the grand discoveries of Davy and Berzelius, three illustrious savants on the possession of whom our era can never cease to pride itself."

There was the more merit on the part of Oersted in thus ranking Berzelius among the great lights of chemistry, inasmuch as Berzelius, rather younger than himself, was his rival in the branch of the science to which he attached the most interest; and it should never be forgotten that if the honor of having completely unfolded the electro-chemical system reverts to Berzelius, Oersted had arrived before him at a closely analogous result, although one less developed. For the rest, what at the present day is of most import to the memory of Oersted in relation to this work, is perhaps the palpable proof found therein of his ceaseless preoccupation with the subject of electrical phenomena. He had conferred great improvements on the pile; he was one among the most practiced experimenters in employing it; he had formally indicated magnetism as one of the phenomena of which it would some day furnish the explanation, and no one was better prepared than himself to advance to the practical realization of this new conquest.

Yet all the attempts thus far made had remained unfruitful. The expedient had been tried of placing the two poles of a battery as highly charged as possible in a parallel line with the poles of a strongly magnetized needle; no effect, however, had been produced. Nevertheless, the conviction still prevailed, especially with Oersted, that a relation must exist between galvanism and electricity. The route to the discovery was unknown, though hazard might open it unexpectedly.

Fortune, it might be said, ceased to be blind at the moment when to Oersted was allotted the privilege of first divining that it was not electricity in repose accumulated at the two poles of a charged battery, but electricity in movement along the conductor by which one of the poles is discharged into the other, which would exert an action on the magnetized needle. While thinking of this—it was during the animation of a lecture before the assembled pupils—Oersted announces to them what he is about to try; he takes a magnetic needle, places it near the electric battery, waits till the needle has arrived at a state of rest; then seizing the conjunctive wire traversed by the current of the battery, he places it above the magnetic needle, carefully avoiding any manner of collision. The needle—every one plainly sees it—the needle is at once in motion. The question is resolved! Oersted has crowned, by a great discovery, the labors of his whole previous life.

It was on the 21st July, 1820, that Oersted communicated to learned Europe the important fact with which his genius had just enriched science. He consigned it to a small tract written in Latin, of only four pages in 4to, which, notwithstanding its conciseness, presented with perfect clearness, the results of more than fifty experiments, and left scarcely anything to be added on the subject. This composition, entitled *Experimenta circa effectum*, etc.—(Experiments on the effect of the electrical conflict upon the magnetic needle)—was addressed the same day by post to all the societies in Europe which occupy themselves with the natural sciences. A French translation of it appeared in the number of the *Annales de chimie et de physique* for August, 1820, from which I transcribe a few expressions employed by Oersted on this occasion:

"The first experiments on the subject I undertake to explain were made in the lectures which I gave last winter on electricity and magnetism. They evinced in general, that the magnetic needle changed its direction through the influence of the voltaic apparatus, and that this effect took place when the circuit was formed, and not when it was interrupted; a process which had been attempted in vain by celebrated physicists, some years before. But, as my

experiments had been made with an apparatus of small energy, the effect of which was not so striking as was called for by the importance of the fact to be established, I invited my friend Esmarch, judicial councillor to his Majesty, to unite with me in repeating them with a more powerful apparatus. We had also for associates and witnesses the Chevalier de Vlengel, MM. Hauch and Reinart, professors of natural history; Jacobson, a very skillful physician and chemist, and Zeise, professor of philosophy. I made other experiments when alone, and if these taught me anything new, I took the precaution of repeating them in the presence of these eminent men of science. * * * In order to make the experiment, we put in communication the opposite poles of the voltaic apparatus by a metallic wire, which we will call, for brevity, the *conducting* or *conjunctive wire*; and we will designate the effect which is manifested in this conductor and around it during the voltaic action by the term *electric conflict*.

"Let us suppose now that the rectilinear part of this wire is horizontal, and placed above and parallel to a magnetic needle freely suspended * * * the latter will move in such a manner that, under the part of the conjunctive wire which is nearest to the negative pole of the apparatus, it will deviate towards the west. * * * If the conjunctive wire is arranged horizontally *under* the needle, the effects are of the same nature with those which take place when the wire is above the needle; but they act in an inverse direction—that is to say, the pole of the needle, under which is the part of the conjunctive wire that receives the negative electricity of the apparatus, inclines towards the east. * * * It appears, from the facts stated, that the electric conflict is not inclosed in the conducting wire, but that it has around it quite an extensive sphere of activity. We may conclude from the observations that this conflict acts by a vertical or whirling movement."

Such was the theory of Oersted: we shall presently see that he was less happy in his theory than in his experiment.

In publishing the memoir of Oersted in the *Annales de chimie et de physique*, M. Arago added a note in which he said that the results there recorded, "however singular they might appear, are accompanied by too many details to leave room for any suspicion of error." He cited, moreover, the experiments of verification made in his presence, at Geneva, by M. de la Rive.

The explanation proposed by Oersted for the capital fact which he had just discovered, recalled in some respects the vortices of Descartes. This did not much savor of the spirit of the present epoch; it met consequently with but little acceptance. At the end of barely a few weeks, Ampère had replaced it by another, based on a law of attraction. I borrow the recital of this scientific event from the spirited and learned *Eloge* of Ampère, read by M. Arago to this Academy, 21st August, 1839:

"The discovery of Oersted reached Paris by Switzerland. In our weekly session of Monday, 11th September, 1820, an academician who had come from Geneva" (it was M. Arago himself) "repeated before the Academy the experiments of the learned Dane. Seven days after, Ampère laid before us a fact much more general than that of the physicist of Copenhagen. In so short an interval of time he had divined that two conjunctive wires, that two wires traversed by electric currents, would act one on the other; he had devised extremely ingenious arrangements for rendering these wires movable, without the necessity of detaching the extremity of each of them from the respective poles of their batteries; he had realized, transformed these conceptions into instruments susceptible of operating; he had finally submitted his capital idea to a decisive experiment. I know not if the vast field of physics ever presented so admirable a discovery, conceived, made and completed with equal rapidity.

"Of this brilliant discovery of Ampère the following statement may suffice: two parallel conjunctive wires attract each other when electricity traverses them in the same direction; they repel one another, if the electric currents move in

opposite directions." The sequel of Ampère's labors showed "that the reciprocal action of the elements of two currents is exerted in conformity with the line which unites their centers; that it depends on the mutual inclination of those elements, and that it varies in intensity in the inverse ratio of the square of the distances." Ampère finally succeeded in establishing that a conjunctive wire wound into a helix with very close spires, is sensitive to the magnetic action of the earth. For many weeks there was to be seen in his cabinet "a conjunctive wire of platina whose position was determined by the action of the terrestrial globe." Ampère, by constructing a galvanic compass, had shown that the forces which act in the magnetic needle are electric currents, and by his learned calculations on the reciprocal action of those currents he accounted for all the actions which the conjunctive wire of the pile exerts, in the experiments of Oersted, on the magnetic needle.

Electro-magnetism had thus become the common glory of Oersted and Ampère, and renown, by uniting the names of these two illustrious savants, not unnaturally calls attention to the resemblances or the contrasts which existed between them.

They were throughout nearly cotemporary, Ampère having been born the 22d January, 1775, and Oersted the 14th August, 1777. Both had entered upon life in a very modest condition as regards fortune; both had had slender means of instruction, and had at first informed themselves with little help from masters and even little from books. Oersted had composed poetry not destitute of merit; Ampère, in his youth, wrote French verses replete with delicacy and grace, some of which have appeared to M. Arago no unworthy ornaments for his eulogy. Oersted always saw in the harmonies of nature a poetry superior to all other poetry; Ampère, in the evening of his life, composed in Latin verse a general tablet of the classification of the sciences, in which elegance disputes the palm with precision.

Oersted, a declared disciple of Kant, applied his ideas to the material world as a consummate physicist; Ampère, an enthusiastic sympathizer with Maine de Biran, Royer Collard, and Cousin, exercised his acute and powerful faculties and manifested a lively interest in disentangling the most subtle problems of metaphysics. Both were skilled in communicating to their learned instructions a peculiar attraction, though each in a different kind. Each of them has left, among friends, colleagues, pupils, remembrances full of that affectionate admiration which can never be effaced.

Oersted made his first scientific essays in the pharmacy of his father; before all else he was a chemist. Ampère, at the age of thirteen, borrowed from the public library of Lyons the mathematical works of Bernouilli; he was born a geometer, but the Encyclopedia having been his first book, he had, from his infancy, embraced all the branches of human knowledge and had even become profound in many of them. M. Arago has felt authorized to say of him, in speaking of his labors in chemical classification, "that, during one of the last revolutions of science, Ampère, the geometer Ampère, proved always in the right, even when his opinions were opposed to those of almost all the chemists of the world."

Without Oersted, electro-magnetism might not have existed; without Ampère, it might have been confined to an exceedingly curious, but limited experiment. The co-operation of Oersted and Ampère made it, in a very little time, a complete science, a science destined to change the face of the world by the surprising applications of it which have been already realized, and in which it is employed entire without distinction as to the origin of its different parts.

I have often heard it asked who was the true inventor of the electric telegraph. Reference has been made to ingenious physicists, who in the course of the last century transmitted to a distance, by means of the electric spark, instantaneous signals. As well might the learned, when the brothers Chappe

had, in 1792, invented the aerial telegraph, recall the fact that the Gauls had transmitted distant signals by means of wooden beams set in motion. Neither the Gauls nor the older physicists had created any regular means of correspondence.

Among those whom I have the honor of addressing, several may be able, like myself, to recall the memorable lectures which M. Ampère delivered at the College of France at the commencement of 1832, in which he had the boldness to express his ideas on the relations of the structure of different classes of animals in contradiction to Cuvier, who lectured in the adjacent amphitheater; ingenious ideas which M. Cuvier overwhelmed at each lecture with peremptory facts, and which M. Ampère, accommodating himself to those facts, reproduced still more ingeniously in his subsequent lecture. In this course, naturally much frequented, and which was in substance a course of experimental physics, M. Ampère spoke one day of electrical currents, and, after having represented on the table four small magnetic needles with metallic wires suitably encompassing them, he explained how an electric current transmitted at will in such or such a manner, by means of these wires, would cause a declination of such or such of these needles in definite directions, so as to produce divers combinations, to each of which might be attributed the value of one of the letters of the alphabet; how, in fine, by varying at will and with the rapidity of writing the mode of propagation of the electric current, words, phrases, discourses might be formed by the succession of these conventional letters.

M. Ampère particularly cherished this idea and often recurred to it in conversing with his friends; but his fertile imagination did not stop with a single process, and sometimes, instead of needles, he proposed the employment of vases filled with water in which should be produced alternately disengagements of oxygen and hydrogen by the decomposition of the liquid. On the whole, it is impossible to deny that from that time the fundamental idea of a future electric telegraph existed among the auditors and friends of M. Ampère. There remained nothing more than to execute it practically. Such execution was rendered much more easy by the result of the experiments of M. Arago on the momentary magnetization of soft iron by the electric current, and by the knowledge of the laws of the remarkable phenomenon of induction, established by M. Faraday.

Every one knows how, from station to station, long metallic threads, placed on insulating supports, have been stretched in order to transmit the electric current from point to point. In the first arrangements of apparatus for this purpose, in that especially which M. Wheatstone established between Paris and Versailles and which was in operation in 1845, the electric current was produced by magnets, for which was afterwards substituted an electric battery, as being susceptible of more energetic action. The conducting wires were reduced, for each apparatus, to a single one, the mass of the earth sufficing for the return of the current. The needles were also reduced to a single one, which stopped in any desired position before a dial-plate bearing on its circumference the 25 letters of the alphabet, the 10 numerals, points, &c. To bring the needle to a certain radius of the dial and to a definite letter, the dentated wheel on which it depended was made to traverse a suitable number of notches, by as often interrupting and re-establishing the electric current. This idea of suspending and restoring the current by interruptions variously diversified, was the most essential addition which had been made to the fundamental idea of Ampère. The interruptions and re-establishments of the current occasion, so to speak, a succession of electric waves, comparable, in a certain measure, to the sonorous waves by means of which our voice is propagated, but infinitely more rapid.

Since these first essays, the mechanism employed has been singularly varied. The dials and needles have been suppressed and replaced by other combinations. A multitude of ingenious instruments, *cut-offs*, *pole-changers*, *manipulators*,

electro-magnets, magnets variously armed, have been devised by a throng of men of talent. This pursuit, still so new, is one of those in which the inventive spirit of our age has most favorably displayed itself; but, whatever the process, it always substantially consists in operating, at a distance and even beyond the seas, with the electro-magnetic currents of Oersted and Ampère.

[This statement can scarcely be considered as correct, even in view of the rhetorical license of the eulogist. The currents used in telegraphing are, strictly speaking, neither the discoveries of Oersted nor of Ampère, but of Volta and of Faraday. There are three different forms of the telegraph: first, that of pure electricity which transmits messages by a galvanic current, and makes signals by sparks or by marks on chemical paper. Second, that of the needle moved by a galvanic current, first suggested by Ampère. Third, that of an electro-magnet which produces sounds, and also marks on paper at a distance. The first of these depends essentially on the discovery of Volta, and the other two on the primary fact of Oersted, extended, applied, and modified by others.—J. H.]

In a very interesting account of Oersted, from which I have borrowed many of the details here cited, professor Hauch, of Copenhagen, compares, with no unjustifiable enthusiasm, his master Oersted discovering, after long meditation, the action of the pile on the magnetic needle and thus opening for science horizons altogether new, to Christopher Columbus discovering America, after having dreamed all his life of the existence of a great continent beyond the ocean.* He might have added that Oersted, more fortunate than Columbus, encountered no Americus Vespucius to dispute with him the glory of his discovery. Ampère, the most modest of men, had need of no glory but his own, if, indeed, he ever occupied himself with that; and moreover, in electro-magnetic science, the parts of Oersted and of Ampère have remained perfectly distinct. If the fundamental experiment is the incontestable property of Oersted, the developments immediately added by Ampère were the fruit of a spirit of invention which yields not in merit to the most original experiment, and of an analytical science which could only be met with in a geometer like Ampère, and, it may be added, in those colleagues of ours who bore a part in his calculations, M. Savary, M. Liouville, and our actual president M. Duhamel.

It pertained to the members of this Academy, the colleagues of Ampère, to be first in proclaiming all the merit of Oersted. The occasion was embraced with the ardor which, in such circumstances, is always native to it. We read accordingly, in the statement regarding the prizes awarded, 8th April, 1822, as follows:

* The first idea of this comparison reverts to Sir John Herschel, as may be seen by the following letter of M. de Humboldt to Oersted, a translation of which has been obligingly communicated to me by M. de la Roquette, former consul of France in Denmark:

"Assuredly, M. Councillor, it will be a pleasure to the King to see you again and to express to you how much his Majesty is personally flattered at receiving among us a man of your celebrity. You are invited for to-morrow noon to the King's table, and in the evening at the new palace to the first representation of Medea in the Court Theater. * * * * * I have just read to-night in Herschel's *Study of Natural Philosophy*, p. 340, this fine passage concerning you: "*In Oersted there is something which reminds us of the obstinate adherence of Columbus to his notions of the necessary existence of the new world, and the sole history of Oersted's beautiful discovery may serve to teach us* * * * * ." This is a just eulogy expressed in very ingenious terms. With the highest consideration, your obedient,

"A. DE HUMBOLDT."

A second letter of M. Humboldt to Oersted, also communicated to me by M. de la Roquette, will further contribute to show with what regard and cordiality Oersted was received at Berlin:

"May I count, dear doctor, on the pleasure of seeing you again before your departure? I desire not only to read once more your instructive memoir on the repose of the volcanoes of Nicaragua, but also to have some doubts respecting Squier resolved. The King being to arrive to-day, I shall be occupied until Friday. On that day or the following, may I flatter myself with the hope of seeing you at Berlin? * * * * * With distinguished consideration, &c. A. DE HUMBOLDT."

"The Academy announced in its public session of the 27th March, 1820, that in that of March, 1822 it would award the prize of mathematics, consisting of a gold medal of the value of 3,000 francs, to the best work or memoir on pure or applied mathematics, which shall have appeared or been communicated to the Academy during the space of two years which are accorded to competitors.

"Many physico-mathematical researches, worthy of high praise, have appeared in that interval. * * * But the importance of the discovery of the action of the voltaic pile on the magnetic needle, a discovery which furnishes a new principle to applied mathematics, and which has already given rise to interesting applications of analysis, has determined the commission to award to it the prize of mathematics. The commission charged with the examination of articles for the prizes of mathematics is in the habit of adjudging those prizes without the co-operation of the Academy. But as the discovery in question is not explicitly comprised in the programme, it has been thought that the authorization of the society should be invoked for awarding the prize to this admirable discovery. This proposal having been submitted to the deliberations of the Academy, was unhesitatingly adopted."

A place having soon afterwards become vacant among the correspondents of the Academy for the section of physics, the nomination of M. Oersted to supply it took place 9th June, 1823. In the sequel, the highest scientific distinction at the disposal of the Academy was conferred on him, 11th April, 1842, by his election as one of its eight foreign associates, to replace the distinguished botanist de Candolle.

The just eclat which had attended the discovery of Oersted, by no means diminished his desire of sometimes placing himself in personal communication with the savants of other countries. In 1822 he again went to Germany, where, independently of those who more peculiarly ranked as savants, Goethe, the illustrious poet, to whom nothing in the domain of intellect was alien, received him with distinction; as is testified by the manner in which Oersted's discovery is spoken of in several passages of his writings.

Oersted was now, for some time, engaged in thermo-electric experiments with Seebeck, and afterwards came to Paris in 1823. The Academy shared the pleasure which he experienced on taking his place in its ranks, and, during his sojourn, was entertained by several series of experiments which he performed in its presence, not the least curious of which were those executed in common by himself and Fourier.* In these, bars of bismuth and of antimony soldered together alternately and forming a closed circuit, were employed. By heating or cooling the solderings, electrical currents were produced which appeared more abundant but less intense than the currents developed by weak hydro-electric action, and gave occasion to many interesting observations.

Towards the middle of summer Oersted passed into England and Scotland, and was received, as he had been in France, with a cordiality and attention which testified the high estimation in which the author of the discovery of electro-magnetism was equally held in those countries. On his return to Copenhagen, he resumed his life of labor with more ardor than ever. The north of Europe then exhibited the spectacle of a brilliant scientific arena. At Stockholm, Berzelius, one of the princes of chemistry, at Copenhagen, Oersted, one of the princes of physics, formed, as it were, two centers of labor and discovery, around which gravitated, like so many brilliant satellites, men destined themselves to a just and well-earned celebrity—Arfvedson, Nordenskiold, Bonsdorff, Mitscherlich, Gustave and Henry Rose, &c.

The noble emulation which established itself between the laboratories of the two capitals is easily conceived. Oersted reapplied himself to chemistry. Resuming at the end of a quarter of a century his investigations of 1799 on alumina, he accomplished, in 1824, a work which placed him in the rank of the

* See *Annales de chim. et de physique*, t. xxxii, p. 375, (April, 1823.)

most eminent practical chemists, and obtained, after prolonged efforts, the *chloride of aluminum.* No one before him had effected the decomposition of alumina. Yet he did not succeed in insulating the aluminum; this last and important step was reserved for M. Vöhler, the distinguished chemist of Gottingen. Still later, our young and learned colleague, M. Henri Sainte-Claire Deville, has formed of aluminum a new and valuable element of metallurgic industry.

One of the last labors of Oersted relates to the celebrated diamagnetic discoveries of our illustrious colleague M. Faraday, whose experiments had already added so many curious facts to electro-magnetism, as well as to the researches made on the same subject by some German savants, especially by M. Reich, of Friburg.

Oersted presented his first results to the Royal Society of Sciences of Copenhagen, 30th June, 1848, and gave a review of them in the *Compte Rendu* of the transactions of the society. He soon afterwards drew up a more complete memoir, which has been published in French.* Therein he recognizes a decreasing magnetic progression which includes the magnetic bodies properly so-called, the attractable diamagnetic bodies, the repellable diamagnetic bodies. The magnetism of these last may, according to him, be considered as negative, if we regard the magnetism of iron and of the attractable diamagnetic bodies as positive. Oersted showed herein that, experiment in hand, he always kept himself abreast of the progress of physics, and particularly of electro-magnetism.

In effect, the weight of years never relaxed the activity of Oersted. Were I to undertake a bare enumeration of the researches and writings of every kind which he executed at Copenhagen during the last twenty-five years of his life, I should much exceed the time at my disposal. But, while omitting this long catalogue, in which are numbered nevertheless important memoirs on electricity and magnetism, on the compressibility of liquids and of gases, on the heat developed by the compression of water, on capillary phenomena, works of literature and philosophy, &c.,† I feel bound to point out what contributed in quite

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* See *Annales de Chimie. et Physique*, 3d series, t. xxiv, p. 424, (December, 1848.)

† The following note, for which I am indebted to M. de la Roquette, makes us acquainted with one of these last works:

"Oersted published, about 1850, two volumes under the title of *Aanden i Naturen*, a philosophic work which appears to me of high import; it forms a series of treatises in which the author introduces us, in a manner at once philosophic and popular, to the study of nature, by revealing to us the eternal spirit which determines all its phenomena, and the relation under which this spirit exists towards the material and intellectual world. The following is the substance of the tracts or chapters of which the work is composed:

"Vol. I. (1) *Of spirit manifested in matter.* The author develops what is constant or immutable in the continual changes of bodies; it is the single thought or design which exists therein. The unity of this thought pertains to nature, for the natural laws, which are constant and invariable, are laws of reason; not of the reason which is in us, but of that which prevails in the entire universe. It is the assemblage of laws determining the activity of an object, which constitutes its real essence. These laws, which may be properly called the ideas of nature, form in every object a unity which may be qualified as the essential meaning of the object or its idea. This idea does not exist solely in the thought; it is realized, on the contrary, in the acting forces of the objects. The being of the object is thus an animated or living idea. In order to place these interesting reflections within the reach of all, the author has recourse to the form of dialogue, like Plato, Fontenella and Fenelon; his style is at once simple and clear, rich and varied. (2) The fountain and the jet d'eau. He here characterizes the different impressions produced by this phenomenon. (3) The relation between the conception of nature by thought and that which is effected by help of the imagination. (4) Superstition and incredulity in their relations to the natural sciences. (5) All existence considered as the empire of spirit. (6) The culture of the sciences represented as a worship offered to God.

"Vol. II. (1) The relation of the natural sciences to poetry. (2) The relation of these sciences to different important notions of religion. (3) Of the salutary influence which the study and employment of the natural sciences must exert on the intellectual development of man. (4) Two discourses on occasion of the reunion of the Scandinavian naturalists. (5) On the passage from the school to active life. (6) Comparison of ancient and modern times; the author here demonstrates that neither the world nor humanity have deteriorated; that the temperature of the air has not changed; (the physical state of Greenland was, six

a special manner to the honor of Oersted, by observing that, in him, the favors of fortune never weakened his devotion to the duties of the savant, and that after having made a discovery whose brilliancy rendered it difficult further to augment his reputation, he believed that he still owed to science and his country the constant tribute of assiduous labor.

It was one of the happy events of Oersted's life that he witnessed, in 1829, under the reign of Frederic VI, the founding at Copenhagen of a *Polytechnic School.* Of this he was named director, an honorable title which he retained till his death. We will not examine whether this Polytechnic School, in which courses were appropriated to the arts and trades, entirely resembled our own. In such a country as Denmark, less extensive than civilized, it is necessary to unite many branches in order to compose a solid faggot. The object was, in the main, analogous, and the very name of the school was a memorial of the first journey of Oersted to Paris, as well as an homage rendered to the celebrated school of Monge and Fourcroy. In the Danish institution, Oersted continued to profess physics till his last year, with unremitting zeal, animation and success. As director, he treated the pupils with a mixture of kindness, sagacity and firmness which secured their unreserved devotion and willing obedience.

During his third journey, Oersted found himself crossing the channel from France to England, on his forty-sixth birthday, 14th August 1823; it is an anniversary which the people of the north style *the day of one's fête.* Accustomed in Denmark to pass it in the bosom of his family and friends, he was now left to his solitary thoughts; and these naturally reverting to his country, inspired him with the design of founding something on his return which should be at once a profitable and pleasant memorial of the vows which on this occasion he addressed to his distant home. The plan of a society for the promotion of the study of nature formed itself in his mind, and was so thoroughly wrought out during the short navigation, that nothing was required on landing at Dover but to reduce it to writing. The plan met with cordial acceptance in Denmark, and by aid of the new association, courses of natural history were established not only at Copenhagen, but in other cities of the country; nor has this institution since ceased to bear the useful fruits which Oersted had anticipated.

He was also member of a literary society. In connection with this a monthly publication was edited, in which he often inserted articles on the most varied subjects, not excepting religious and philosophical ones. He belonged, moreover, to an association established for the right use of the liberty of the press. In fact, his co-operation seems to have been claimed almost universally at Copenhagen, nor was a sense of its value without frequent manifestations in other cities of Denmark, and even in those of the neighboring countries. To the last, he was accustomed to make numerous excursions as well into the north of Germany as into the Scandinavian peninsula, in attendance on the assemblages of naturalists which were held at different places. It was a cherished idea of his that, through these assemblages, not only might the exchange of scientific views be facilitated and a more intimate union among the representatives of science be cemented, but that their benefits might be extended to a wider circle by expositions placed within the reach of all and contributing to introduce, even among the popular masses, the habit of comprehending and mutually exchanging their idioms and forms of literature; especially was it his hope that the three Scan-

hundred years ago, the same that it is to-day;) the olive had in France, eighteen hundred years ago, the same limit in the north which it has at present; the men of antiquity were not stronger and attained not a more advanced age than those of modern times; the human race, far from retrograding, has made sensible progress in regard to morals. (7) The relation of the natural sciences to different ages and to their philosophy; * * * Christianity and mental cultivation as lending each other mutual support."

The interest which this work excited in Germany led to its translation under the title of *Der Geist in der Natur*, (The Soul in Nature). [It was also translated into English.]

dinavian nations might thus become, as it were, three branches drawing in common their intellectual nourishment from the same radical stock.

It was never the misfortune of Oersted to witness any diminution of reputation. In 1846, in the sixty-ninth year of his age, he again traveled into Germany, France and England. In an interesting notice of Oersted read 7th November, 1851, before the Royal Society of Sciences of Copenhagen, M. Forchhammer, who had accompanied him, tells us that this journey resembled an ovation. In England, especially, Oersted was received by the most eminent politicians and men of science with a distinction which has rarely been the portion of a stranger, and, above all, of a simple savant. His purpose was to take part in the meeting at Southampton of the British Association for the Advancement of Science. In one of the sessions of that body, Sir John Herschel, made an address to him, remarkable for the signal and intelligent justice which it rendered to his scientific labors.

Honored in his public, Oersted was happy in his private life. His younger brother, whom he had taught to read under the roof of the wig-maker of Rudkjöbing, ever continued to be his faithful and intimate companion. The latter had himself acquired great celebrity by his labors in philosophy and jurisprudence, and had filled the position of president of the Royal Society of Copenhagen. Only with the death of the elder brother terminated the auspicious habit, contracted in childhood, of daily exchanging their impressions and ideas. In 1814, Oersted had espoused Mademoiselle Brigitte Ballum, daughter of a Lutheran minister of Kjedby, in the isle of Möen, and found in her an accomplished companion, whose character, admirably adapted to his own, formed their mutual happiness. Of five daughters and three sons born of this union, only three of the former and two of the latter survived Oersted, to be the consolation of their mother. One of his daughters is married to M. Sharling, professor of chemistry in the University of Copenhagen, long known for important researches on respiration.*

Around Oersted, however, there existed a still more extensive family. It was composed, we might say, of the whole city of Copenhagen, where he was as much loved as esteemed, as much esteemed as admired. Of this his fellow-citizens gave him a touching proof in the latter days of his life. The day (7th November, 1850) which marked the fiftieth anniversary of his entrance upon public duties, and was what is called in the north *his jubilee*, was celebrated by a general festival in Denmark, with the somewhat quaint forms of Teutonic good-fellowship, but accompanied by a substantial testimonial of gratitude to the man who was regarded as the honor of the whole nation. It had been determined by the friends, the pupils, and indeed the simple admirers of the philosopher, to make this the occasion of securing to him for the remainder of his life the possession of Fasanenhof, (Pheasant-court,) a delightful summer residence in the garden of Fredericksburg. The choice of the dwelling was so much the more delicate and so much the more pleasing to Oersted from its having been previously the habitation of Oehlenschläger, the friend of his youth.

Oersted was conducted thither on the day of his jubilee. At the same time the King raised him to the rank of councillor of private conferences, a title never before conferred on a professor of the university, and much higher than that of councillor of ordinary conferences, which Oersted had borne for ten years. His bust, executed by a celebrated statuary, was set up at Fasanenberg in presence of an immense crowd, in which were intermingled the most illustrious personages of the kingdom. The rector of the university formally presented

* His treatise on respiration was published in 1843, some months before the researches of MM. Andral and Gavarret on the same subject. (*See Comptes Rendus* of the Academy of Sciences, t. xvii, p. 1205.) M. Alexandre Oersted, son of the celebrated jurist M. André Sandöe Oersted, and nephew of the renowned physicist, is at present professor of botany in the University of Copenhagen.

him with the gold ring of a doctor, on which was engraved a head of Minerva encircled with diamonds. The Seigniory of the association of students notified him that he had been elected an honorary member of that society, and a deputation of the Guild of arts and trades tendered him thanks for what he had done in behalf of the industry of the country.

To all the discourses addressed to him Oersted replied with a force, a composure and a choice of expressions which surprised the assistants. The choir of the students commenced and terminated the fête with a chant, the words of which had been composed by one of the best poets of Denmark. In the evening a procession with torches and a new chant by the students greeted the object of this enthusiastic commemoration.

The day on which classes so numerous and so diversified had vied with each other in testifying for him their affection and admiration must have been to Oersted one of the sweetest of his life. He had received from his sovereign and his fellow-citizens the most exalted testimonials of esteem with which any Danish savant had been ever honored, and, in spite of his modesty, his conscience could not have failed to insinuate to him that he was not unworthy of them. The hope of passing his last years, surrounded by his family and dedicated to a tranquil scientific activity, in the smiling retreat which his countrymen had thought proper to offer him, was calculated to blend the satisfaction of the heart with the consecration of his renown. Yet this pleasing hope was but a deceptive gleam, and although his mind, still vigorous, and his frame replete with life, seemed yet to promise length of days, it was not granted to Oersted so much as to take possession of his new domicil, for before the return of spring he had ceased to live.

He died at Copenhagen, 9th March, 1851, at the age of seventy-three years and seven months, removed unexpectedly and in but a few days, by a simple catarrh contracted by studying of a morning in too cold an apartment. His death was a profound and general grief for the city of Copenhagen and for all Denmark.* In that grief, this Academy, in common with the whole scientific world, bore no indifferent or simulated part.

Oersted was replaced in the list of our eight foreign associates by the celebrated chemist of Berlin, M. Mitscherlich, to whom crystallography is indebted for the most important progress it has made since Haüy. M. Mitscherlich had, in his youth, associated himself with the labors of the Scandinavian scientific school; and this choice, justified by other reasons, might be regarded as a new and last homage rendered to the memory of Oersted as well as to that of Berzelius.

No scientific body had been backward in crowning with its suffrage the great discovery of Oersted. To make an enumeration of more than fifty societies which inscribed his name among those of their correspondents or their foreign associates, would be little less than to draw up a complete list of the principal Academies of the two hemispheres. More than one sovereign had been emulous of associating himself with the movement of public opinion in his behalf. He was advanced to the class of grand-cross of the Danish order of Danebrog, grand-cross of the Swedish order of the Polar Star, member of the order of Merit of Prussia, and officer of the Legion of Honor.

Oersted was not only eminent as a physicist, profound as a thinker, he was a man of rare excellence of character. Author of one of the capital discoveries of the century, promoter of one of the schools which confer most honor on his country, founder of many important scientific and literary institutions, dear to the youth and to the public of Copenhagen, whom he had charmed during 50 years by a system of poetic and philosophic ideas in harmony with their natural instincts,

* Two-hundred thousand persons, preceded by the princes of the royal family, followed the body of Oersted to its resting place.

he had never failed to avail himself of the credit which his high position in science had given him with an enlightened government, and even of the friendship of a well-informed King*, to render innumerable services to studious youth, to savants less fortunate than himself, to a multitude of persons whom he recognized as worthy of his countenance. Had his characteristic modesty not equaled his other merits, he also might have adopted the boast ascribed by a poet to his hero :

Some little good I've done—it is my noblest work.

* Prince Christian of Denmark, who reigned afterward under the title of Christian VIII, was an eminent mineralogist and deeply versed in many parts of the sciences.

NOTICE OF CHRISTIAN FREDERIC SCHOENBEIN, THE DISCOVERER OF OZONE.

Translated for the Smithsonian Institution, from the "Archives des Sciences Physiques et naturelles," Geneva

The death of C. F. Schoenbein has sent a pang of regret not only through Switzerland but through the scientific world. We cannot better fulfil the painful duty of reviewing the life of this eminent man than by borrowing the following pages from a notice published in the Basle *Nachrichten*, for which we are probably indebted to the pen of Professor Hagenbach:

The mortal remains of Christian Frederic Schoenbein have been carried to their last resting place. He has been so suddenly arrested in a life full of activity, so abruptly called away, that we can hardly realize he has ceased to be among us. These pages which we now consecrate to his memory can only faintly express the sentiments awakened in us by the loss of one so much beloved and so much mourned. The complete appreciation of his scientific career cannot be given in a few rapid sketches.

Schoenbein was born the 18th of October, 1799, at Metzingen, Suabia. From his parents he received a limited, though religious, education. He left the paternal roof at the early age of 14, in order to enter an establishment for the manufactory of chemicals; but a mere practical career could not satisfy his aspirations; the occupation only awakened in his youthful mind an ardent desire for the more elevated science of chemistry. He commenced the study of Latin, and went to the universities of Tübingen and Erlangen. After he had finished his studies at the universities, he taught chemistry and physics in a school at Keihan, near Rudolstadt. Afterwards, he pursued his scientific education in England and in France, and at length, in 1828, went to Basle, where he was installed as lecturer on physics and chemistry. This office was formerly intrusted to Counsellor Merian, who still continues his active career among us. An attack of illness obliged him to discontinue this course of instruction, by which he had rekindled the love of those sciences which of old were so brilliantly represented at Basle by such men as James and Daniel Bernoulli.

In 1835 Schoenbein was elected full professor of physics and chemistry in the University of Basle, and discharged the duties of this position without interruption until 1852, when the professorship was divided into two distinct chairs, he retaining that of chemistry and continuing in it until the time of his death. Thus, Schoenbein has been connected with our university nearly 40 years, and has never, except temporarily, during that period quitted Basle; his two longest journeys, the one to England the other to Germany, are well known from the accounts of them which he has published, and to which the mingling of serious and humorous observations with scientific reflections and sketches of personal adventures give a peculiar charm.

Schoenbein was married in the year 1835, but the tranquil happiness which he found in domestic life was unfortunately disturbed by the sudden death of his eldest daughter in 1859, an event which sadly afflicted his entire household.

His energies were unreservedly consecrated to science, and he always remained faithful to the counsels of his master, the celebrated Schelling, who taught him to regard her as his bride. Thus all his faculties, all his efforts were continually exerted to draw nearer each day to scientific truth, and to penetrate ever more profoundly into the mysteries of the forces which govern the changes of the

material universe. He worked with ardor and an indefatigable perseverance, and all the time he could command was employed in his experiments; even the short wintry days found him at early morn in his laboratory. When astonishment was expressed that one of his advanced age should be so eager in the pursuit of science, he was wont to say, with a smile, that he knew "there remained for him but little time in which to work, and that there was still much flax upon his distaff."

He preserved to the end all the freshness of his faculties as well as the juvenile enthusiasm with which from the first he had made known his discoveries to his colleagues and to the scientific world.

Among the works of Schoenbein we may first mention those which relate to subjects which are neither entirely physical nor entirely chemical, but which rather appertain to both, such as his researches upon the passivity of iron and of other metals; the changes of color of bodies under the influence of temperature; the chemical action of luminous rays, and finally the theory of voltaic electricity. In this latter domain he has thrown much light upon the well-known controversy relative to the theory of contact and chemical action; in studying with impartiality the two opposite opinions, and in demonstrating wherein they were faulty. He ascribes the origin of voltaic electricity to chemical action, although he showed a positive difference between the electricity developed in the open current of the battery and that which produces the current and the chemical decomposition which are manifested when the current is closed.

His researches on the voltaic current date from 1836 to 1840; since that epoch his views relative to the source of the voltaic current have become gradually adopted by physicists in general. In 1839, while in England at the meeting of the British Association, he made the personal acquaintance of the celebrated English lawyer and physicist, Grove, who presented at the session a small voltaic battery, of which the cells were constructed of the bowls of tobacco pipes; this was the first exhibition of the celebrated constant battery which bears the name of its inventor. As Schoenbein had been engaged on a similar investigation, we soon see the two physicists pursuing the same object. They planned one of these batteries of large size, and thus produced an apparatus which, in proportion to its dimensions, exhibited an unusual electro-motive force. This first large constant battery is still preserved in the Museum of Physics at Basle, a souvenir of Schoenbein and of Heussler, a friend of science brought up among us, who bore the expense of its construction and gave it to our academy. The possession of this apparatus gave to Schoenbein a fresh incentive to resume with new energy his researches upon the relations of electric and chemical forces. Thanks to this battery it became possible to decompose water into its elements in greater quantities than had ever before been done; it was during an experiment of this kind that, in the autumn of 1839, he perceived a peculiar odor from the oxygen obtained by the decomposition of water similar to that produced when a large electrical machine is in active operation, or when a discharge of lightning takes place between a cloud and the earth. This odor he at first attributed to a new substance mixed in small quantities with the oxygen, and as this body ought to have a special name, after consulting with his colleague, M. W. Kischer, he gave it that of ozone.

His first publication of the discovery of ozone excited but little attention in the scientific world. But nowise disheartened by this, he continued his investigations with a persistency only to be met with among those who are thoroughly possessed with a subject. He pursued during 29 years, or what may be considered the active life of a man, the same end, the study of the chemical properties of oxygen; a labor which, though it might appear to lead to no valuable results, is really connected with the properties of one of the most important elements of our globe.

In consequence of his own researches and those of other physicists, Schoenbein was soon forced to renounce the idea that ozone was an elementary substance, and

to recognize in it a peculiar condition of oxygen in which it is endowed with special properties.

We cannot here enumerate the many discoveries connected with this subject, and still less retrace the important steps that have been made in the domain of chemistry and of physiology in connection with it; we must limit ourselves to the remark that Schoenbein has contributed much to enlarge the field of science in this direction, and as the names of Priestley, Scheele, and Lavoisier are mentioned in connection with the early discoveries relative to oxygen, so the name of Schoenbein will always be recalled when we speak of the new form under which this element appears, and the varied action, when thus changed, it produces upon organic and inorganic bodies.

Among the discoveries which have rendered Schoenbein known, even beyond the scientific world, we must mention that of gun-cotton. This substance was not doomed merely to administer to the malevolent passions of men, and to play a destructive part in war, as its name would seem to indicate; the subsequent discovery of Schoenbein gave it functions of a more pacific character; a solution of gun-cotton in ether forms collodion, an admirable dressing for wounds, and a precious ingredient in the art of photography. The first application of collodion as a medicinal agent was made at the instance of Schoenbein by his friend, Dr. Jung, of Basle.

The tardiness that Schoenbein found in the acceptance of his ideas on their first presentation was afterwards fully compensated by the approbation they received from all parts of the scientific world. The most distinguished philosophers of Germany, of France, and of England adopted essentially by his views, and several learned societies, among others the academies of France and Munich, elected him a corresponding member.

His manner of working deserves to be noticed. However important the results at which he arrived, the means that he employed for obtaining them were extremely simple. There is no doubt that the great progress made in modern times in the construction of apparatus and instruments of research has had an important influence on the development of science, but the investigations of Schoenbein show us what can be effected, at least in some lives, without the aid of costly appliances.

Schoenbein was so much occupied with his special researches that it is not surprising he did not keep entirely posted up in the general progress of chemistry. Though he by no means confined himself exclusively to the special objects of his investigations, yet he could not give to other branches that study which was necessary to render them fully appreciated. He did not adopt the views and the methods of the leading chemists of this day; he often compared the production of the varied combinations of the same elements with the rotation of a kaleidoscope, giving constantly new images, doubtless amusing, but not very instructive. He also frequently compared chemical phenomena to a theatrical exhibition, in which many regard only the *denouement* of the last act, while it is often in the development of the drama that the most interesting truths are exhibited. In the judgment which he formed of the ideas of other philosophers, Schoenbein may have been at times somewhat prejudiced. The vivacity of his mind often presented to him in too strong a light the defects in the conceptions of others, while the preoccupation of his thoughts with his own ideas left him no time to reflect upon them with calmness and impartiality.

His peculiarity as a professor will remain as a precious souvenir to many. It follows, from what we have said relative to his manner of work, that his specialty was not to exhibit the actual state of science and to deduce from it the various theories which have been devised. The most remarkable feature of his course was the ardor of his connection and the clearness with which he discussed his favorite subjects; it was not only instruction in science but also the love of science itself that he imparted to his pupils, and for which many among them will always remember him with gratitude.

Schoenbein did not limit his instruction to the course of the university; he understood in the best possible manner how to impart his knowledge to others. Above all, we should speak of the activity which he imparted to the Society of Natural Sciences of Basle, of which, during 40 years, he was a prominent member; he considered it as a dear friend, to whom he always first confided his most important discoveries. The published proceedings of this society give the entire series of the results of his scientific labors. The Helvetic Society of Natural Sciences lost in him one of its most zealous and valued members; he almost always animated the meetings of the physical section by interesting communications, and this year, at the session of Einsiedeln, his absence was noticed and deeply regretted; the society, feeling the want of his cheering presence, transmitted to him by telegraph a friendly salutation; alas, this found him upon a sick bed, soon to become his bed of death. All the inhabitants of Basle, interested in sciences, were indebted to him for the series of interesting lectures which he addressed to the public of that city. In former days he gave complete courses of popular instruction, and in later years he did not refuse to share the efforts of younger men in the organizations for the same purpose. But his enthusiasm for instructing extended beyond the confines of the lecture-room, in society, in the street, even at the refreshment saloons he knew how to give a scientific turn to conversation without assuming the pedantic tone of a master. Schoenbein knew how to gain the hearts of all by his amiable qualities, and consequently numbered many friends. But his general popularity did not prevent him from contracting close friendships, to which he remained faithful during life; he was intimately attached to several of his colleagues, of whom some have preceded him to the tomb; the youngest of his associates felt that it was not only benevolence but a true friendship which attached him to them. Among the foreign philosophers with whom he was on terms the most intimate, and with whom he regularly corresponded, we may mention Faraday, Grove, Liebig, Wöhler, Eisenlohr, Pettenhofer, Sainte Claire Deville, and Sebetellen de Metz, author of a well-known work on ozone.

The meetings of the Helvetic Society furnished him the opportunity of intercourse with the savants of Switzerland. He was particularly associated with M. M. Escher, Studer de la Rive, Pictet, Heir, Desor, Lang, and many younger philosophers who also shared his friendship.

If we would sum up in a single sentence the character of Schoenbein, we should say that at all points of view he represented an individual of peculiar development; he was an original in the best sense of the term, and such men ought to be more appreciated, as they become ever more rare in our age of universal mediocrity. Schoenbein was a complete man, for although an absorbing idea, the love of science, governed his entire life, yet, all his other faculties had received an entire and vigorous development. His general health was good; he was hardened against exterior influences. It is but a short time since he worked during the middle of winter in an unheated laboratory. For several years he suffered occasionally from attacks of gout, from which, however, he always completely recovered. On this account he resorted, during the vacation of last summer, to Wildbad, thinking to fortify himself for the approaching winter. In returning, however, he was detained at Sauersberg, near Baden Baden, at the house of a friend by an abscess on his neck, which, rapidly assuming a dangerous character, rendered his return home impossible. The greatest care and medical aid could not arrest the march of this disease, and on the 29th of August he died peacefully in the house of his kind and attentive host. His obsequies took place at Basle, the 2d of September. The funeral was conducted by friends, among whom was Eisenlohr, who had visited him on his death-bed. A long train of colleagues, pupils, relations, and admirers accompanied him with emotions of deep sorrow to his last resting place.

APPENDIX TO NOTICE OF SCHOENBEIN.

[The phenomenon called passivity of metals mentioned in the foregoing eulogy as one of the discoveries of Schoenbein, consists in the fact that iron, for example, which, under ordinary conditions, is readily disolved in nitric acid, may while in a peculiar state remain for weeks in the same liquid without being acted on. This phenomenon is, without doubt, due to a galvanic action, which, when the iron is first plunged into the liquid deposits a coating of oxide which protects the metal from the further action of the acid. To illustrate this let a piece of clean iron wire be immersed in strong nitric acid together with a slip of platinum, the former being introduced first and the two connected with the ends of the wire of a galvanometer, a powerful current will be inducted at the first completion of the circuit, the iron acting as the positive metal, but the strength of this current will quickly decline to a small amount and then remain constant for several days. The iron thus treated is no longer attacked when plunged alone into nitric acid, and is said to be *passive*. Instead of using a galvanometer, which was merely introduced to prove the existence of a galvanic current, the same effect will be produced by touching the iron wire while the acid is acting on it with a piece of gold or platinum, also immersed in the liquid, the action will immediately cease and the iron become passive. When an iron wire in the passive state is plunged into nitric acid and the upper end touched with another iron wire, as soon as dipped into the acid the latter also becomes passive. In these experiment, the iron, which is rendered passive, acts as the zinc element of a galvanic pair, and is rapidly covered with an oxide which protects it from further action except of a very feeble character. In this state it may serve as the copper or negative metal of a galvanic pair, and really performs this part in the second experiment in which a galvanic couple is formed by the contact, while in the acid, of the passive and non-passive iron. The formation of an oxide sufficiently thick to protect the iron is not produced in nitric acid, of ordinary strength, unless a galvanic arrangement such as we have described is adopted, but if it be plunged into very strong acid the action, though violent for an instant, will soon cease, and the metal assume the passive condition. If this wire be withdrawn from the acid and exposed to the air for a short time, or rubbed with sandpaper, it will resume its ordinary state. An iron wire may also be rendered passive by holding it for a few minutes in the flame of a spirit lamp.

Other metals—namely, silver, copper, tin, aluminum, and especially bismuth, may be brought into the passive state by the methods we have mentioned, but the effect is not as marked as with iron. Dr. Hare constructed a galvanic battery in which the platinum was represented by iron in the passive state, but the action was capricious; though at one moment powerful at another it became almost nothing.

Another discovery of Schoenbein, mentioned in the foregoing sketch, is that of *gun-cotton*, a very explosive substance, produced by steeping cotton-wool in fuming nitric acid, or in a mixture of nitric and sulphuric acids, afterwards washing and drying the product. This discovery was announced by Schoenbein in 1845, but the mode of preparation was kept secret. It was, however, soon rediscovered independently by Bettger and Otto, while Kopt improved the process of production by the addition of sulphuric acid to the active liquid. From the first it was proposed as a substitute for gunpowder, over which it possesses the advantages of burning without smoke, and leaving no residuum to foul the chamber of the cannon. Large establishments were erected for its preparation, but the

occurrence of several severe accidents during its production, attended with great loss of life, caused it to be regarded as too dangerous for military purposes, and, accordingly, its manufacture was for a time almost abandoned. Within the last few years, however, the attempt to make use of it as a substitute for gunpowder has been renewed and brought to a successful issue by an Austrian officer of artillery.

Gun-cotton is used in military operations in the form of a spun yarn, in which it conducts combustion slowly in the open air at a rate of not more than one foot per second. This yarn is used to form cartridges for large guns, by being wound round a bobbin, so as to form a hollow spindle and thus give an interior surface for the action of the flame and the production of the most effective explosion. The effect of the explosion of gun-cotton under water is remarkable; the action is so instantaneous that the water has no time to yield, and consequently transmits the impulse as a solid material; hence it is unnecessary to place the charge in immediate contact with the body to be destroyed. In one experiment two parallel rows of piers, 10 inches thick, in water 13 feet deep, with stones between them, were blown to pieces by a barrel of 100 pounds of gun-cotton, placed at a distance of three feet from one side and eight feet under water. It made a breach of 15 feet, and threw the water to a height of 200 feet. In another experiment with 400 pounds of gun-cotton a vessel was blown up, the pieces projected into the air to a height of 400 feet, and the fishes for nearly half a mile around were so stunned as to float on the water. The rapidity of expansion and great elastic force of gun-cotton renders it a valuable agent in blasting. Its power when exerted against a great resistance, as in the case of splitting a rock, when compared with that of gunpowder, is in the ratio of $6\frac{1}{4}$ to 1.

The discovery which has rendered the name of Schoenbein most extensively known is that of *ozone*. Before the end of the last century Van Marum, of Holland, had observed that when an electric discharge was passed through oxygen the latter acquired a peculiar smell and the power of attacking mercury, but it was not until 1840 that any notice was taken of these facts, when Schoenbein published his first paper on ozone. In this he announced the fact that in the decomposition of water, by means of a galvanic battery, an odorous gas was given off at the positive pole, and that this might be preserved for a long time in a well-closed vessel. He also pointed out the fact of the similarity of this odor to that which accompanies a discharge of electricity, especially from points, and also the slow oxidation of phosphorus. Opinions as to the cause of the odor were long divided, but through the experiments of Schoenbein and the investigations of Andrews, and Tait, and others, it is now generally referred to oxygen in a changed or allotropic condition.

One of the simplest methods of exhibiting the production of ozone consists in transmitting a current of oxygen through a glass tube, into the sides of which a pair of platinum wires have been sealed, with their points a small distance apart. On connecting one of these wires with the prime conductor of an electric machine, in active operation, while the other is connected with the ground, the odor of ozone is immediately perceptible in the stream of gas. But in order to produce a maximum effect it is necessary to transmit the discharge silently in the form of a brush or a star, since sparks appear to produce an opposite effect, and are, therefore, to be avoided. Ozonized air may also be obtained by placing a stick of clean, moist phosphorus in a bottle of air or oxygen, when, after an hour or so, the smell of ozone will be obvious. The stick of phosphorus is then to be taken out and the gas washed with water to remove the phosphorous acid. Or ozone may at once be produced by plunging a heated glass rod into a mixture of air and a vapor of ether. The galvanic decomposition of water acidulated with sulphuric acid, or better, perhaps, with the addition of chromic acid, affords at the positive pole a large supply of ozone. The general characteristics of ozone are those of an oxydizing agent; it corrodes organic matter, as shown in

its energetic action on the caoutchouc tubes through which it is conducted. It bleaches most vegetable colors; it changes the black sulphide of lead into white sulphate, the yellow ferrocyanide of potassium into the red ferrocyanide. It oxydizes moist filings of iron, copper, mercury, and silver. In some cases, however, ozone acts as a deoxydizing agent. It decomposes peroxide of iron and barium. It exists in variable quantities in the atmosphere, and its presence is indicated by what is called ozone test-paper, namely, paper steeped in iodine of potassium, which is rendered brown by the liberation of the iodine. If starch be added to the solution in which the paper is steeped the ozone produces a blue color; but according to some authorities this test is not as reliable as that of the solution of the iodide of potassium alone. As ozone is an energetic oxydizing agent, it combines with animal matter and other impurities in the air, and hence its absence, as evinced by the want of coloration in the test-paper, is considered as an indication of the presence of malaria in the atmosphere of the locality in which such indications are observed. It is evident from what has been stated that ozone must be produced in the atmosphere by electrical discharges, but whether it exists from other sources in the air is at present unknown. Neither are the test-papers we have mentioned decisive proofs of its relative quantity, since there are other substances generally present in the air which are competent to produce similar effects.

One of the most plausible hypotheses as to the nature of ozone is that of Clausius, who considers all gases, whether simple or compound, as made up of a number of atoms combined together to form molecules. That, for instance, a molecule of oxygen consists of at least two atoms, and that it may happen that a portion of each of the great number of molecules which exists in a given quantity of oxygen can be decomposed into two atoms which distribute themselves in their separate state among the remaining undecomposed molecules, and that these isolated atoms, which in their relations to foreign bodies must differ from the molecules of ordinary oxygen, constitute ozone.

In accordance with this hypothesis, the production of ozone by passing electricity through oxygen or atmospheric air may be attributed simply to the repulsive power of the electricity by virtue of which the two atoms of oxygen, being charged with the same kind of electricity, are driven apart, as in the case of the well known experiment of two pith-balls. When oxygen is evolved in the decomposition of water, a similar repulsive separation takes place at each pole or electrode, but most of the atoms immediately combine again upon the electrodes to form ordinary oxygen. A small portion only of the atoms remain in a separate condition, and these constitute the ozone with which the oxygen is mixed. Finally, in the case in which ozone is developed during the oxidation of phosphorus in moist air or oxygen, we may suppose that the atoms which make up the oxygen molecules are in different states or degrees of electricity; that one of these tends more energetically to combine with the phosphorus than the other; and that the latter, removed from the sphere of its attraction by the heat generated in the combination of the former, remains in an isolated condition. The fact that these atoms do not immediately recombine into molecules to form ordinary oxygen may be due to their similar electrical state. When ozonized air is heated, the ozone disappears, because the high temperature determines the union of the atoms as it does of hydrogen and oxygen in the application of a flame to a mixture of these two gases. It has been found that the ozonification of oxygen by the electrical spark or brush can only be carried on to a certain extent if the ozone remain mixed with the oxygen; but if the ozone be removed as rapidly as it is formed by the oxidation of silver, all the oxygen may be gradually converted into ozone. In this case, when the number of separate atoms become too great in a given space, they are brought within the sphere of mutual attraction; combination ensues, and the ozone dis-

appears as fast as it is produced in the reproduction of ordinary oxygen. The power of combination with metals and other bodies exhibited by ozone becomes a consequence of this hypothesis, inasmuch as separate atoms must from analogy have more combining power with foreign bodies than atoms which are already in combination with each other.

The hypothesis of Clausius is very suggestive, and with a few supplementary assumptions can be made not only to render a plausible explanation of known phenomena, but also to indicate new experiments. It must be stated, however, that it is at variance, as presented in the foregoing sketch, with the experiments of Soret on the density of ozone. This chemist finds, from an elaborate investigation, that when ordinary oxygen is converted into ozone its density is increased instead of being diminished, as it should be, according to the hypothesis of Clausius. This result was arrived at by two different methods, that of absorption and that of diffusion. Both gave approximately the same result, from which it appears that the density of ozone is one and a half times that of oxygen. According to the hypothesis of Clausius a molecule of oxygen consists of two atoms, and may be represented by 00, while an atom of ozone would be indicated by 0. From this it is evident that the density of ozone should be only one-half of that of oxygen. In order to make the hypothesis of Clausius agree with the result obtained by Soret, we must suppose that while an element of oxygen consists of two atoms, and is represented by 00, an element of ozone consists of three atoms represented by 00,0; that when by electrical repulsion or other action, the two atoms of oxygen are separated, one of them immediately unites with a molecule of ordinary oxygen and the other to a second molecule, forming two molecules of ozone out of three molecules of oxygen. Or, in other words, by the decomposition of one of three molecules 00 00 00 of oxygen, and recomposition with the remaining two, we shall have two molecules 00,0 00,0 of ozone. It is not necessary that we should limit a molecule of oxygen to two atoms; on the contrary, we may suppose that it consists of an indefinite number provided we admit that under the action of electricity or other forces it is divided into two portions, each containing an equal number of atoms. In the present state of science, if we adopt the atomic constitution of matter, we must consider what was formerly assumed as the ultimate atoms of bodies, as groups of atoms held in relative position by attracting and repelling forces. It is only by an assumption of this kind that we are enabled to obtain a mechanical conception of matter in any degree applicable to various chemical and physical phenomena.] J. H.

MEMOIR OF ENCKE.

By G. Hagen.

*Translated for the Smithsonian Institution by C. A. Alexander.**

Last year died the director of our observatory, Professor Encke. Besides his other scientific and serviceable labors, he acted for eight and thirty years as secretary of the physico-mathematical class of our Academy, and during that long interval administered the affairs pertaining to the office with the utmost disinterestedness, skill and discretion.

Johann Franz Encke was born in Hamburg, September 23, 1791. His father, archdeacon in the Jacobi-church at that place, died four years afterwards. Although his mother brought to the rearing of her eight children remarkable energy of character, yet the moderate pension which the family still drew from the church by no means sufficed for the expense of extensive studies.

As a preparation for the business of life Encke first resorted to a private school kept by Hipp, the author of several mathematical works, and later, from 1805 to 1810, frequented the Johanneum, where Hipp was still his teacher. Under these circumstances he very early developed a singular predilection for mathematical studies. At this time he voluntarily imposed on himself the task of repeatedly going over the collection of problems propounded by Meyer-Hirsch, and is stated in the parting certificate awarded him, October 11, 1810, to have been a model to his school-fellows for diligence, correctness of deportment, and modesty.

It was now that he expressed to his mother the wish to study astronomy, and his two elder brothers, who had entered into trade and who recognized his talent, devoted themselves to the furtherance of his purpose, which they were enabled to gratify through the intervention of the pastor, Schäfer. During a year he attended a gymnasium in Hamburg, and proceeded in 1811, shortly after the death of his mother, to Göttingen. Here an older fellow-countryman named Gerling introduced him to Gauss, whom he was accustomed afterwards to regard as pre-eminently his instructor, and to whom he referred almost exclusively his mathematical and astronomical culture. Especially instructive did he consider an entirely private course *(privatissimum)* which, together with Gerling, he attended in the summer of 1812, at the residence of Gauss, who, on his own part, in a letter to Schumacher of this date, already calls Encke "his highly accomplished and well-informed pupil."

Political events led Encke, in the beginning of 1813, to enter into the Hanseatic artillery service. He was engaged in the bloody fight for the fortress of Göhrde, September 16, where Wallmoden attacked and defeated the corps which Davoust had despatched thither under Pecheux. He also took part, the following month, in Tettenborn's bold advance upon Bremen. In the honorable discharge granted him, June 24, 1814, he is styled sergeant-major of cavalry.

He resumed his studies in Göttingen, but as the war broke out anew the following spring, he at once decided, in company with his younger brother who

*Abhandlungen der königl. Academie der Wissenschaften zu Berlin, 1866. Read 5th July, 1866, before the Royal Academy of Sciences at Berlin

was studying theology, to serve under the Prussian standard. He seems to have affixed to his offer of service a testimonial wherein Gauss certifies that Encke had "at first attended and afterwards borne an active part in his manifold astronomical occupations and labors, and had manifested throughout distinguished talent, great diligence, and uncommon knowledge." The brothers were required to undergo an examination, which, in the case of our astronomer, at least, was never repeated. He received, June 10, 1815, the commission of second lieutenant of artillery, and was first ordered to Thorn, and later to Graudenz.

Encke would, probably, like his brother, have still further pursued a military career had not Von Lindenau, the director of the Seeberg observatory, at the recommendation of Gauss and Gerling, offered him in the beginning of 1816 the place of adjunct therein. This induced him to ask a discharge from the army, which was accorded on the 8th of March. Hereupon he went once more to Göttingen, and remained there till July 5, 1816, when his nomination to the observatory was confirmed. The appointment was by no means dazzling. The salary was but $15 a month, and the place of service consisted of a garret so lowly that he touched the ceiling when he raised his hand above his head. Not the less did there go forth from hence such labors as soon turned the general attention on the young astronomer. With so much zeal did Encke apply himself to his duties that only once a week did he leave the observatory and go to Gotha.

He first occupied himself with the newly discovered small planets, especially Vesta, whose orbit he traced with superior accuracy, and of whose apparent motion he published the ephemerides. Another labor, if one of subordinate importance, was not without consequence by placing him in friendly correspondence with Bessel. The *Fundamenta Astronomiæ* had been printed at Gotha, and Lindenau, on whom the correction of the press devolved, transferred this task to his assistant. Encke, however, did not confine himself to a comparison of the manuscript with the impression, but repeated the calculations. Hence Bessel says, in the preface to his work, "Mr. Encke, who occupies the second place in the Seeberg observatory, but who would be an ornament to the first, has given himself with unsurpassed skill to the revision of the imprint, even to the detection and correction of the errors of the manuscript. I must acknowledge this with the more thankfulness, inasmuch as his time is worthily occupied with his own astronomical researches, and between us no other bond exists than that which embraces all who devote themselves with zeal to the same science."

The first of the more important labors of Encke relates to the comet of 1812.*

This had been observed for two months at all the greater observatories. Encke had, at his first residence in Göttingen, and therefore immediately on the appearance of the comet, begun the calculation which, in the well-considered and careful employment of numerous observations and the exact execution of extended computations, takes rank with the most admirable investigations of this nature. It was crowned with a special result, since an elliptical orbit corresponded with the revolution of nearly 71 years.

How important this discovery was considered at that time is seen from a letter of Bessel's: "You have adduced the strongest proof for the shortness of the revolution of this comet, and placed the result in the clearest light. We have now, since we begin more narrowly to observe and to calculate the comets, quite other views to maintain. Halley's comet seemed only to be an exception. As regards that of Olbers, I scarcely trusted my own calculation, as this gave but a middling revolution. Yours is now the third. Our successors, through an exact investigation of the planet-masses, will be enabled to recognize the true movement of the heavenly bodies with a perfection of which we have scarcely an idea."

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* In the second volume of the *Zeitschrift für Astronomie und verwandte Wissenschaften*, p. 337 *et seq.*

Encke immediately thereafter addressed himself to a similar yet more troublesome inquiry. The editors of the *Zeitschrift für Astronomie* had chosen as the thesis for the prize offered by Cotta, the computation of the orbit of the comet of 1680. This comet, on account of its luminosity, the length of its tail, which comprised 80 degrees, as well as the duration of its visibility, had presented one of the grandest phenomena of which the history of the heavens makes mention. It had been extensively observed by the astronomers of the period, especially by Flamsteed, Newton, and Cassini, though the observations had been limited to the measurement of the distances of the fixed stars, and the comets' place had been in part only estimated, inasmuch as the observers had been content to suppose the body bisected by two great circles drawn through four neighboring stars, which circles only approximately touched it.

Encke wrote to Bessel that, at the special request of Lindenau, he would attempt the solution of the problem, and with this view requested the communication of a number of stellar positions from the catalogue of Bradley. With this request Bessel at once complied, but expressed the apprehension that the result would scarcely justify the expenditure of time, as he deemed the observations too uncertain. And, indeed, of so large a number of measurements there were but few that were available. In many cases it was even uncertain from what fixed stars the distances were measured. Nevertheless it was found, on critical examination, that Flamsteed's observations disclosed a high degree of accuracy, since their probable errors amounted to but 15 seconds of arc spherical. With due regard to planetary disturbances this orbit was also shown to be elliptical, and the period of revolution was found to be 8,813 years.

Gauss cordially congratulated Encke "on this admirable prize essay, to which he was indebted for so much pleasure." Bessel expressed himself in more specific terms: "It is without example that the more ancient observations have been reduced to so small a probable error. We learn from this, that to a good astronomical result there is indispensable, besides a tolerably good instrument and a capable observer, an able calculator also. If the last be wanting, the rest is little worth."

Together with these great labors Encke occupied himself in many ways with the incidental calculation of cometary orbits. As often as one was discovered, and had been for some time observed, he was accustomed to publish, not only its orbital elements, but, to facilitate further observations, its ephemeris as well. The constant practice and fine perception which guided him in the choice and grouping of the observations enabled him to arrive with wonderful certainty at a correct result. A remarkable example of this was furnished by the third comet of 1819, for which Encke, from some scanty Marseillese and a few Milanese observations, so accurately calculated the elements of an elliptic orbit and a revolution of 5½ years, that on the re-discovery of the comet at the Bonn observatory after seven revolutions (in the year 1858) no important qualifications were admissible. This practical knowledge and perspicacity led, no doubt, to the discovery through which Encke's name is most generally known.

A comet was discovered November 26, 1818, by Pons at Marseilles, the path of which, as Olbers soon remarked, was nearly coincident with that of the comet of 1795 and 1805. It had been already surmised that the orbit was elliptical and the period of revolution short beyond example. The elucidation of this remarkable circumstance was probably undertaken by many astronomers, though it was Encke who first succeeded in shedding complete light upon it. The time of revolution amounted to 1,207 days, or nearly 3⅓ years, and it was this comet respecting which Bessel had expressed a conjectural opinion that it moved in an elliptical orbit.*

In a communication on this comet Olbers extols "the skill, the care, and the

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* In the *Berliner Astronomiches Jahrbuch* for 1822, which was published in 1819.

genius" which Encke had lavished on the calculations. Bessel, who had heard of the comet during an absence from Königsberg, wrote to one of his scholars: "It becomes clearer and clearer that this comet is the most important scientific discovery of the present century." Olbers also expressed himself in the same terms in a letter to Bessel.

Although the short period was in itself of the most pregnant consequence as affording the prospect of a more certain determination of the masses of the planets which exert an influence on the comet, yet further investigation soon led the way to another wholly unexpected result. Encke found, in effect, that this comet had been observed, also, in 1786, and hence four times in all, while no less than seven times in the interval its return had not been noticed. From a comparison of the three intervals between the observed transits it resulted, with all due allowance for the planetary disturbances, that each revolution, as regards the next preceding one, had been shortened by about three hours.

Olbers was the first to conjecture that the comet encountered a certain resistance whereby its approximation to the sun, and, consequently, the shortening of its period of revolution might be accounted for. Encke concurred in this view, while Bessel dissented from it. In the correspondence between the two, the reasons for and against the hypothesis were, for many years, fully discussed. In 1830 Bessel writes: "What admirable results are yielded by careful labor is now again seen in the conformableness of that unknown disturbance which you call resistance. Of the existence of such disturbance there can be no doubt, nor could there be long ago, but that it is a real resistance becomes more problematical to me the more I reflect upon it."

Encke continued assiduously to observe this comet, which he always called the comet of Pons, though his own name was, with perfect justice, commonly applied to it. Before each of its returns he made known its ephemeris in order to facilitate observation, and as the shortening of the period of revolution constantly recurred, in which fact he saw a confirmation of the above hypothesis, he developed, in 1831, his theory of the movement of heavenly bodies in the resisting medium. For the constants introduced, the values admitted of determination from foregoing observations.

Halley's comet, which re-appeared in 1835 after a period of 76 years, occupied very exactly the same positions which Rosenberger had previously calculated from the earlier observations. By this body, therefore, the hypothesis of the resisting medium was not confirmed, though it was by no means decidedly contradicted, because neither the earlier measurements nor the masses of the planets relied upon as a ground of calculation could be regarded as altogether certain; perhaps, also, this comet might have a denser mass, and the effects of resistance be on that account not so conspicuous.

The comet discovered still later by Faye seemed at last to remove the doubt previously existing. The period of this body, 7½ years, was, according to Möller's computation, shortened at each revolution by about 17 hours, and Encke showed (*Berliner Astronomisches Jahrbuch für* 1864) that this acceleration could, with very close approximation, be explained by the resistance which the comet of shorter circuit had undergone. In the meantime Möller communicated the results of a more rigorous calculation, (*Astronomische Nachrichten*, vol. 64, p. 145,) in which were considered those quantities of the second order in the co-ordinates of the disturbances which arise from the changes sustained by the elements through the addition of new fundamental places at the more recent returns. By this it was found possible to bring all the three phenomena into harmony without the assumption of the resisting medium. The errors remaining over were, through this procedure, it is true, considerably greater than after the first calculation, but Möller entertained the hope of being able, by a renewed and stricter calculation, to attain a still closer conformity. Whether, therefore, Faye's comet does or does not confirm the hypothesis of the resisting medium,

or, in more general terms, that of a yet unknown cause operating upon both comets, still remains undecided.

Two other important investigations of Encke related to the sun's parallax, as derived from the transits of Venus in 1761 and 1769, the last of which Cook had observed at Tahiti. After correction of the observations, revised by Father Hell in Vienna, Encke found the parallax to be 8.57 seconds. "You have turned to account," wrote Bessel, "what had been collected by the expenditure of vast sums and by the efforts of many, and thus those efforts have first achieved success and still point onward to a step in advance." This magnitude of the parallax was for a long time generally accepted; but subsequently, from the opposition of Mars and the disturbances of the moon, was estimated at 8.9 seconds. The difference between this value and that found by Encke arose from the circumstance that the position of the places of observation was not ascertained with the requisite precision. After a more accurate determination of this point in later times, the sun's parallax, as deduced from those old observations, has been shown by Powalky to amount to only 8.832 seconds.*

Encke's personal position had so far changed, soon after his accession to the observatory, that the charge of its management had devolved on him, at first partially, through the intermitting attendance of Lindenau, and soon wholly, from the absorption of the latter in administrative affairs. As no other duties claimed his time, Encke could now resign himself to scientific labor with free and entire devotion. The value which he placed upon this rare immunity is seen from a letter in which he declined an appointment tendered him of a professorship in the University of Greifswald. The chair of mathematics and astronomy had there become vacant by the death of Professor Droysen, in 1814, and for some years no successor was appointed. Bessel called Encke's attention to this, and as, in regard to external circumstances, the situation presented great advantages over that of Seeberg, proposed to recommend him for it. The philosophical faculty at the same time consulted both Gauss and Bessel in regard to a choice. The preference of Gauss fell upon Gerling, who had already approved himself as a teacher, though next he recommended Encke, whom, in regard to knowledge and capacity, he rated quite as highly. Bessel, on the other hand, named Encke in the first place: "He is a young man whose character is as amiable as his acquirements in astronomy and mathematics are distinguished; nor is his skill as a practical astronomer less so. Many are the admirable labors for which we are already indebted to him, evincing a diligence and conscientiousness beyond praise."

To the question now addressed by the faculty to Encke, whether he would permit himself to be placed in nomination for the office, he replied, March 16, 1818, as follows: "My place here as adjunct of the observatory I have now occupied for two years, and must, in justice, regard it as eminently fortunate, seeing how much my student years were abridged by the distractions of the war, that I have been assigned to a position so wholly free from the demands of other business, provided with so excellent a stock of instruments, under a director (Herr Von Lindenau) whom Germany honors as one of its first astronomers, and where, in short, it is permitted me to live exclusively for science. This position has at present so far changed that the director, involved in many other affairs, and but just returned after a year's absence, has no prospect but to be again and repeatedly absent in the course of the current year. Under these circumstances my employers have taken occasion so clearly to indicate their wish that I should remain here, that I should little respond to their previous kindness were I not ready to forgo the great advantages proffered me by the Greifswald University.

* [This element has been recently investigated at the Naval Observatory, Washington, by Professor Newcomb, from all the more valuable data of recent times, and its value is thus fixed at 8″.85, with a probable error of not more than two or three hundredths of a second. J. H.]

How highly soever, therefore, I may appreciate the honor of the proposal made to me, I am under the necessity of declining its acceptance."

We learn from a note by Gauss that the ducal government had taken the occasion of this call to increase the salary, and also to confer upon Encke the title of professor. Two years later he was named vice-director, and in 1822 director of the observatory.

In the last named year Walbeck died in Abo. Encke, though widely solicited to propose for the vacant place, could not be induced to comply, though here again the opportunity of greatly bettering his circumstances was presented to him. The grounds of his refusal were freely communicated to Bessel, and among them we find his recently contracted marriage: he was unwilling to transport his young wife to so northern a latitude.

Not the less did the discomforts and inconveniences of the residence at the observatory continue to be sensibly felt. During storms it was impossible to leave the building or have access to the city. Even with moderate winds the stroke of the pendulum clock could not be heard, and thus the observations were rendered difficult. Particularly annoying to Encke was the loss of the library, which belonged partly to Zach and partly to Lindenau, and which, in 1822, was withdrawn by both owners. At last, however, the prospect of a favorable change offered itself. Tralles, till then secretary of the physico-mathematical class of our Academy, had died in 1822. Gauss was nominated as his successor, but at the close of 1824, after long negotiations, peremptorily declined the offer. At the same time Bode took his discharge, and it thus became practicable to unite with the above named place that of director of the academical observatory.

Bessel wrote to Encke, February 16, 1825, that this place had been offered to him, but that he had unconditionally declined, because he could not leave his own observatory. He had named Encke as the only one suited for it. The academy had approved of the proposition, and committed to him the negotiation respecting it. He goes on to say: "You will see what rare fruits will proceed from our co-operation. I know your modesty, and feared that you might not deem yourself qualified. To any such objection I oppose the firm conviction that you, and you alone, are fully qualified for the position; and I expect you on this point to believe me rather than yourself, which, in view of your modesty, cannot be so very difficult."

Encke answered that he hoped indeed that he was competent to the continuance of the journal *(Jahrbuch)* and the execution of astronomical calculations, though he must absolutely decline if the demands went any further. Bessel, who was just setting out on a journey to Berlin, wrote, March 20: "I will make inquiry about everything, and when I learn that your wishes in regard to the definite occupation can be complied with, and if a suitable provision be stipulated, I shall, in your name, say yes. Do not be startled at this liberty which I am taking. You can limit it by a letter which will reach me at Berlin."

Such a letter accordingly came, but it contained no decided refusal, and hence Bessel could write in reply: "You have not forbidden the agreement, so I now hold you fast; you are now one of us."

The election which ensued in the academy was confirmed by the higher authorities, and Encke was named, June 21, member of the academy, secretary of the class, and director of the observatory. The ducal ministry, at the head of which Lindenau then stood, soon after accorded him a discharge from his previous situation, adding that "it dismissed so distinguished an official with regret, and only not to be a hindrance to his prospects in life."

Encke arrived at Berlin, October 11, 1825. He soon felt himself on a level with the duties devolved on him, and found complete satisfaction in their discharge. He was not bound to make reports to the university, but he voluntarily adopted the practice the following year. By the philosophical faculty of the university the honorary diploma of doctor was conferred on him, September 11,

1826, as a testimonial "to the sagacious mathematician and successful investigator of the cometary system"—*mathematico sagacissimo, cometarum indagatori felicissimo.*

Previously to these events an important scientific undertaking had been set on foot by Bessel—the editing, namely, of stellar charts, which should represent, in 24 sheets, the zones included between 15° north and 15° south latitude, with all the stars, to those of the 9th and 10th magnitude, which could be discerned with a Frauenhofer comet-searcher of 34 lines opening and tenfold magnifying power. Very soon after Encke's accession the academy invited the friends of astronomy to participate in the enterprise, stipulating a suitable honorarium for each available sheet. It was Encke who undertook the correspondence in regard to the repartition of the task, as well as the critical examination of the sheets and care of the engraving. The business part thus assumed, while in itself the most unthankful of the whole, was rendered more difficult because those who contracted engagements often failed to fulfil them, and sometimes what was produced did not answer to the requirements. At the close of 1858, and hence after 33 years, the last sheet made its appearance. The results of this undertaking surpassed, even before its completion, all expectation. The first discovery of a new planet, Astræa, occurred in 1845, and others rapidly followed. At present, with the use of these charts, or in consequence of the completeness rendered attainable by them, 81 planets have been detected, while the discovery and observation of comets have been essentially facilitated.

The editing of the astronomical Annual *(Jahrbuch)* had still occupied Bode on his withdrawal from the observatory. The tables for 1829 had already appeared and the calculations for the following year been begun, when Bode died, November 24, 1826. Encke undertook the continuation, and as the tables in their then extent and precision no longer satisfied the new demands of science, it was found necessary to give them greater enlargement and completeness, as well as to employ a still more rigorous computation. If Encke in this labor availed himself of extraneous help, it was still so exacting that he was constrained at once to forego his lectures at the university.

What acceptance the new Annual found with astronomers may be gathered from Bessel's letters. "This is indeed an ephemeris," he said, "such as it should be. You make an offering of yourself for astronomy, and one can but wish that the progress which you aim at in doing so may indeed be realized, and that the result may correspond to the magnitude of the sacrifice. I have always thought that an ephemeris of this calibre must produce great results, but I had not believed that any one would subject himself to so great a trouble" * * "I have been completely charmed with your work, and confess that I can imagine nothing more complete. It is all excellent. But explain to me, I pray, why it is that the French have not a *Connaissance des Tems* and the English a *Nautical Almanac* such as your Year-book affords, although both, and especially the latter, do not want for money to pay hosts of calculators. But what is absent, in fact, and is almost always absent, is the clear insight into science and its true wants."

In the course of the following year many complementary improvements were introduced, the Annual for 1844 being especially enlarged, at the instance of the ministry of commerce, by several extensive tables for the use of mariners. These, however, were but little employed in the Prussian marine, chiefly for the reason that the sea charts were constructed with reference to another meridian, that of Greenwich, and the nautical tables in question were withdrawn from the Annual for 1852 and the following years.

The Berlin observatory, in Dorothea street, which Encke had undertaken to conduct, answered not long to the demands of the new astronomy. It had been erected in 1711, and was furnished with the instruments corresponding to that period. It was situated, at first, without the city, but Berlin had in the meantime spread so much in that direction that high buildings overtopped it. About the year 1800 the necessity was seen of adding an additional story, but the

steadfastness of the instruments was thereby still more prejudiced, and the concussion of the intercourse in the streets hindered all exact measurement. To this must be added the continued noise and the impurity of the atmosphere. Encke wrote, soon after his arrival, to Bessel, that the only serviceable instrument was the Frauenhofer heliometer, though this, too, could scarcely be used on account of the insecure stability. The best thing about the observatory was the library, limited as it was.

After Bode's death the erection of a new observatory was canvassed, and if at first Encke expressed himself with some humor about the proposed destination thereof, he nevertheless soon entered earnestly into the scheme. Bessel urged him to consider well "whether the satisfaction in the possession of an observatory or the hindrance to those labors to which he owed his renown, were greatest." In a following letter it is said: "I regard you as the astronomer on whom the superintendence of the calculations is obligatory. Others have other functions: you, my dear Encke, can undertake nothing new without neglecting what has earlier claims upon you, and is in reality of more essential importance. Be cautious, I pray you, in this matter."

Encke now addressed himself to Humboldt with the request that he would decide upon the proper objects of an observatory for this country. Ordinary observations, such as can here be scarcely conducted, are at present, he argued, without value. If it were proposed to afford opportunity for serviceable astronomical observations, a new observatory would be indispensable. This communication led Humboldt to second the movement for building a new observatory, which was authorized October 15, 1828, at the same time with the ordering of several important instruments from artists of the best repute. The purchase of a large refractor, which Frauenhofer had nearly finished, immediately followed.

Encke's questions drew from Bessel a prompt answer respecting the judicious arrangement and equipment of the observatory, but still accompanied with precautionary counsels: "I think that neither your efficiency nor satisfaction will gain anything if you convert yourself into an observatory astronomer. In my opinion the observatory should not be the main point with you. An assistant, adjunct, or whatever you may please to call him, should do the work therein. Immeasurably more is to be done in order to save the material collected from being lost and suitably to use it. If this is once accomplished, it will be then for you to show to what ends further observations may be directed with the most fruitful results."

In the beginning of 1835 the building was finished, the instruments soon after put in position, and the activity of the new observatory commenced with the observation of Halley's comet. The observations which, since that epoch, have been instituted, partly by Encke himself and partly by his assistants, have been published in four volumes, which will soon be followed by a fifth.

How close were the friendly relations between Bessel and Encke is seen from the foregoing communications. They were knit still more closely when Encke took charge of the corrections of the press for the *Fundamenta Astronomiæ*. After Bessel, on a journey in 1819, had formed a personal acquaintance with Encke, he wrote to him: "I see in you not only a firm stay of astronomy in Germany, but a cherished and outspoken friend; both considerations prompt me to wish that you should continue to accord to me a portion of your affectionate regard."

On his return to Königsberg Bessel spoke with enthusiasm of the gifted and estimable astronomer whose first labors had deservedly raised him to the highest consideration. The correspondence which followed was not restricted, like that between Olbers and Bessel, to scientific communications and the more serious affairs of life, but was rather a confidential intercommunion, which embraced at once their respective enterprises, whether begun or contemplated, and the frankest utterances on subjects of every nature. It is not to be disguised, however, that Bessel gave freer scope to his feelings, while Encke often observed a certain degree of reserve. This intercourse had already lasted some years, when we

find Bessel constrained, as it were, to beg of "the highly respected professor" that he would not allow their correspondence to languish. "You cannot do me the injustice to suppose that any one in the world is dearer to me and more highly confided in than yourself. Wherefore, then, a formality which, on my part, has been long ago discarded?"

That views and conceptions should sometimes have differed was, of course, inevitable. The differences, however, were calmly discussed in the correspondence, but they failed not progressively to become more and more pronounced and frequent. The last friendly letter Bessel closed with the words, "I cannot imagine that different relations should find an entrance between us." Not the less, however, did such relations find entrance, and that immediately. The occasion was given far less by any single controverted points which had arisen in the course of astronomical journalism than by the contrast of personal position. Bessel, easily excited in oral as in written intercourse, as warmly maintained the opinions which he conceived to be right as he emphatically repelled those opposed to them, and so sometimes forgot that he who had begun earliest had not only erected himself into a master, but expressly assumed a higher and more influential position than was his due. Thus in one of the last letters Bessel styles himself "the experienced friend," and, as such, thought himself authorized to counsel and warn, whereupon Encke explained "that he could only take the course which alone was consonant to his nature."

Since 1837 only a few formal and professional letters had been exchanged. When Encke, however, in 1845, sought to obtain Bessel's views with regard to a new edition of the treatise of Olbers on the calculation of the orbits of comets, he made, as in earlier years, various communications respecting his own labors, and added the assurance of his deepest concern for Bessel's afflictions. The answer, besides the desired opinion, conveyed a thankful acknowledgment. At the close of the same year Encke communicated the first result of the stellar charts in the discovery of a new planet. A mutual approach was thus again in progress, when some months later the death of Bessel occurred.

The words which, from this place, Encke 20 years ago dedicated to the memory of Bessel, contain the fullest recognition of his great services in behalf of astronomy, but make no mention of the friendly relations which had existed between them. On that subject nothing could be ventured without, at the same time, recalling their later and well-known estrangement. However much that estrangement is to be regretted, it now no longer forbids us to recur to a friendship which not only endured with singular devotion for 30 years, but was of great importance for the advancement of science.

It only remains to recount the occupations of Encke's life during the last ten years. The extensive calculations for the Year-book, if, to a certain extent, devolved on the assistants, continually required his co-operation, and the more as the numerous newly discovered planets were to be taken into consideration. The academical functions connected with the editing of the stellar charts, the discourses before the university, the participation in the observations at the observatory, and in the accurate testing of the new and older instruments there deposited, together with his activity in the commission of studies for the military academy, and in the deputation respecting the calendar, to say nothing of the manifold inevitable demands which await the director of an observatory in a large city, all these appear so engrossing that we have only room for wonder that Encke should still have found time for the communication of so large a number of scientific papers to the transactions of the academy, the astronomical Year-book, and various mathematical and astronomical journals. Many of these relate to the execution of calculations, such as the method of least squares, interpolation, the mechanical quadrature and the like. They are chiefly of astronomical import, and bear relation to the parallax of the sun and moon, the dimensions of the terrestrial globe, the constants of the Berlin observatory, the masses of the planets, the determination of the orbits of planets and those

of comets; the latter as well with reference to parabolic as elliptical and hyperbolic orbits; the calculation of occultations and transits, the testing of different astronomical instruments, and in an especial manner the disturbances arising from the approximations of the heavenly bodies. Not only did he set forth in more than one treatise, and, with singular clearness, rules for the calculation of these disturbances according to the old method of Lagrange, as perfected by Gauss and Bessel, but almost simultaneously with the younger Bond at Cambridge, in America, he suggested a new method by which the calculation of the orbital elements of many of the recently discovered small planets was essentially facilitated. By this, instead of the changes which the disturbances produce in the elements of the orbits, it was proposed immediately to calculate those which the rectangular co-ordinates undergo. This method, if somewhat uncertain for long periods of time, was, on account of its convenience, extensively employed, till the later method devised by Hansen became more generally introduced. Encke also composed some physical treatises on dioptrics and the ballistic problem, as well as several popular lectures on different astronomical subjects. The latter, though but partially published, were distinguished for an ingenious co-ordination of facts, and were received with unqualified applause.

Towards his numerous friends and acquaintances Encke maintained that uprightness of intention which, with his sympathetic and open nature, his clear and unperverted judgment, won him the highest consideration and love. In his domestic circle the course of a serene life was disturbed by no loss until, in 1856, the news arrived of the death of his second son at Rio Janeiro.

On the 17th of November, 1856, Encke fell in the street from sudden vertigo. Although the apprehensions at first felt were not realized, yet the rare vigor of earlier years did not return. A new and severe loss befell him the next year in the death of his brother, the same with whom he had entered the Prussian artillery, 45 years before, and who had since been advanced to the rank of lieutenant general. A few years later he lost his sister, who had lived in his house. In February, 1863, he sustained an apoplectic attack, from which he so far recovered as to be able to return to his labors, and even to journey to Leipsic in order to witness the nuptials of his old scholar, professor Bruhns, but his condition remained so critical that soon all intellectual effort was forbidden him. He therefore spent the summer with his friends in Goslar and Wernigerode, and, on his return, was still bent upon resuming his labors, but his physician, the more effectually to prevent this, ordained him a new journey to Kiel; from Kiel he went with his family in December, 1863, to Spandau, where his eldest son was established. At his urgent and oft repeated request he was permitted by his medical adviser again to visit the observatory. Here he traversed with interest the observing rooms, and marked with particular attention the changed erection of the great refractor, which was now borne upon a stone pillar instead of the old wooden support. He soon tired, however, and returned contentedly to Spandau. From this time his bodily strength and mental activity continued to decline, until a second apoplectic attack occurred in July of the next year, and was followed by complete paralysis. A painless death released him, 26th August, 1865, from long sufferings.

If Encke's services in behalf of astronomy secure him an enduring remembrance, it continues also to survive in the grateful recollection of his numerous pupils. In the calculations for the Year-book, as well as in the prosecution of other astronomical labors, he delighted to find himself surrounded by young people, to whose instruction in all parts of knowledge he gave himself with a rare talent for conveying it; ever entertaining with them the most friendly relations, and thus winning to the pursuit of his science a number of pupils unequalled, perhaps, by any other astronomer. Among them may be counted the present directors of the observatories of Berlin, Breslau, Leipsic, Hamburg, Bilk, Copenhagen, Helsingfors, and Dublin, who, with many others, have contributed through their scientific labors greatly to extend his reputation.

MEMOIR OF EATON HODGKINSON,

PROFESSOR OF ENGINEERING, UNIVERSITY COLLEGE, LONDON.

BY ROBERT RAWSON.

(*From the Transactions of the Literary and Philosophical Society of Manchester, England vol. II, third series,* 1865.)

The subject of this memoir was born, of respectable parents, at the small village of Anderton, in the parish of Great Budworth, Cheshire, on the 26th of February, 1789; died at Eglesfield House, Higher Broughton, Manchester, June 18, 1861, in his seventy-second year, and was interred at his native village. His father died when he was about six years of age, leaving his mother with three children, whose education and maintenance depended upon her exertions and prudence. He left his native village, with his mother and sister, at the age of 22, and came to reside at Salford, Manchester, where he remained the greater portion of his after life. He was elected a member of this society in the year 1826, and he enriched the society's memoirs with the following important papers, thus laying the foundation of his reputation as a sound mathematician and an original thinker:

"On the Transverse Strain and Strength of Materials," (read March 22, 1822.)

"On the Chain Bridge at Broughton," (read February 8, 1828.)

"On the Forms of the Catenary in Suspension Bridges," (read February 8, 1828.)

"A few Remarks on the Menai Bridge," (read December 12, 1828.)

"Theoretical and Experimental Researches to ascertain the Strength and best Forms of Iron Beams," (read April 2, 1830.)

"Appendix to the Paper on the Chain Bridge at Higher Broughton, Manchester."

"Some account of the late Mr. Ewart's paper on the Measure of Moving Force, and of the recent applications of the Principle of Living Forces to estimate the effects of Machines and Movers," (read April 30, 1844.)

He occupied in succession the distinguished positions of vice-president and president of this society. He was a leading member of the British Association for the Advancement of Science from its commencement, and contributed greatly to the interest and efficiency of the mathematical and mechanical sections. He also gave active help to the association in several valuable reports on pure and mixed science. These reports, which have in a great degree assisted in maintaining the high scientific renown of the association, are as follows:

Third report, 1833: "On the Effect of Impact on Beams." "On the direct Tensile Strength of Cast Iron."

Fourth report, 1835: "On the Collision of Imperfectly Elastic Bodies."

Fifth report, 1835: "Impact upon Beams."

He held the distinguished position of vice-president of the association in the year 1861.

In the year 1841 he was elected a Fellow of the Royal Society, and contributed to its transactions two elaborate papers:

"Experimental Researches on the Strength of Pillars of Cast Iron and other materials," (read May 14, 1840.)

The aim of this paper was greatly extended in the second communication:

"Experimental Researches on the Strength of Pillars of Cast Iron from various parts of the kingdom," (read June, 1857.)

For the first paper the council of the Royal Society awarded the gold medal as a mark of their appreciation of its practical investigations.

He was appointed professor of the mechanical principles of engineering at University College, London, on the 6th of February, 1847, and lectured during the sessions of 1847 to 1853, inclusive. In 1847 he was appointed a member of the royal commission to inquire into the properties of wrought and cast iron and their application to railway structures. The results of his labors in this important inquiry are given, with marked reference to their magnitude and efficiency, in the commissioners' report of 1849. He was consulted by the late Robert Stephenson in reference to the construction of that great national work, the tubular bridge over the Menai straits. His experience and mathematical knowledge enabled him to suggest and carry out a series of experiments, at the cost of several thousand pounds, with a view to investigate the bearing properties of wrought iron rivited tubes, and to satisfy the mind of this great engineer as to the stability and safety of the Britannia and Conway tubular bridges. He edited an edition of "Tredgold on Cast Iron," to which he added a second volume, giving an account of his own experiments and discoveries, published by Weale, 1846. The title of the second volume is, "Experimental Researches on the Strength and other Properties of Cast Iron, with the development of New Principles, calculations deduced from them, and inquiries applicable to Rigid and Tenacious Bodies generally."

The most novel and important conclusions here given are as follows:

The strengths of long pillars of cast iron, wrought iron, cast steel, and Dantzic oak, of the same dimensions, are in proportion to the numbers 1,000, 1,745, 2,518, 109. Cast iron is not reduced in strength when its temperature is raised to 600°.

The sets, in cast-iron beams, vary nearly as the square of the force of deflection; hence any force, however small, will injure the elasticity of cast iron. The strength in tons of beams approaching the best form is measured by the formula $2.166ad \div l$, where $a=$ area of section of bottom flange in the middle, $d=$ the depth in inches of the beam, and $l=$ the distance in feet.

A general investigation of the position of the neutral line is given on the principle that the forces of extension and compression of a particle vary as any function of its distance from the neutral line. This includes every hypothesis which has been proposed in order to compute the strength of material bodies subjected to strains.

BIRTH AND EDUCATION.

As I have already stated, Mr. Hodgkinson was born at Anderton, Cheshire, in the year 1789. His father, a respectable farmer, died of fever when his son Eaton was about six years of age, leaving Mrs. Hodgkinson with two daughters and a son. On his father's decease his mother determined to continue the farm; and by industry, thriftiness, and business-like habits she was enabled to educate her children respectably, and to send her son to the Grammar School of Northwich. At this school he received the rudiments of a classical education, as he studied the Latin, Greek, and Hebrew languages under the immediate supervision of the head master, Mr. Littler. This was done to meet the wish of his uncle, the Rev. Henry Hodgkinson, rector of Aberfield, Berkshire, who was very anxious that his nephew should be educated with a view of going to Oxford or Cambridge, to prepare for the church. The desire of his uncle was, for a time, gratified, and the hope was strongly indulged that one day Eaton Hodgkinson would be a student of one of the universities; hence the study of classics in his early youth was considered indispensable, although it was not exactly in conformity with his tastes and habits of thought, as at an early age he was naturally more inclined to the study of mathematics than of languages.

To the severe treatment which he here suffered, his cousin, Mrs. Thompson, attributes the nervous tremor of his hands and speech which continued with him through life, and was a serious impediment to his success. The Rev. Mr. Littler was a very severe disciplinarian, and if a boy could not learn he tried to flog it into him; and young Hodgkinson, owing to his inaptitude for languages, having received a sound thrashing for not having learned his lessons perfectly, was removed from the grammar school and placed in a private school in Northwich of far less pretensions, but more in unison with his aspirations.

This private school, to which he was removed because he did not show a decided taste for the study of languages, was conducted by Mr. Shaw, a gentleman of superior mathematical attainments, and possessing great tact in teaching and in the general management of boys. It was at this school that Mr. Hodgkinson finished his youthful education. He obtained a good degree among his school-fellows, and a distinguished position in the affections of his master. The instructions of Mr. Shaw in mathematical subjects were fully appreciated by Hodgkinson, and consequently he made rapid advances in the various studies to which his attention was directed. Here he laid the foundation of that mathematical knowledge which he afterwards applied with singular success to the extension and development of the theory and practice of the strength of materials. The bias of Mr. Hodgkinson's mind at this period, and the position in which his mother was left, seemed to require a reconsideration of his future. He was now growing in stature as well as in knowledge, and his mother found him very useful to her in the outdoor work on the farm; therefore it was deemed desirable to abandon the idea, once strongly entertained, of prosecuting her son's education with a view of entering the church, and to allow him to devote his attention and energies to the skilful management of farming.

Mr. Hodgkinson therefore gave up all thoughts of the church, and Latin, Greek, and Hebrew were changed for more congenial subjects of study. He commenced at once his career as a Cheshire farmer; but although he felt it a duty to assist his dear mother, and meet her wishes to the best of his ability, still he made but little progress in his new vocation. Farming, which had been thrust upon him by sheer necessity, was not suited to his genius; but he pursued it for a time as a paramount duty, from which his conscientious devotedness to his mother and sisters would not allow him to escape. The seeds of pure and mixed science, which had been thrown broadcast into his youthful mind by Mr. Shaw, were now beginning to germinate, and to rise from their latent state into full and sensible existence, creating, as they advanced to maturity, new wants and fresh desires, which could not be gratified by farming or the society of a Cheshire village. The fruit thus developed at the village school indicated, with unerring certainty, a different direction from Cheshire farming or the church. His mother saw this, and she was ready to bend to circumstances which she could not successfully resist. Hence he persuaded her to give up her farm in Cheshire, and embark her small capital in a pawnbroking business at Salford, Manchester. Their friends advised this step, as the best to promote the interests of the family and satisfy the thirst of Mr. Hodgkinson for scientific knowledge and society. The family, therefore, moved from Great Budworth, Cheshire, to Salford, Manchester, in the year 1811, when Mr. Hodgkinson was about 22 years of age. This step was the turning-point of his career, and but for this in all probability he would have past a life of inglorious ease in a Cheshire village, unknown as a cultivator of mathematical and physical science.

His residence in Manchester was soon productive of important consequences; his habits of thought became fixed, and the line of scientific inquiry in which he was to advance was not long left indeterminate. Manchester at this period was in its youthful vigor; it contained men of great intellectual endowments, each anxious to distinguish himself in some department of useful knowledge; among these the names of Dalton, Henry, and several others stand out pre-eminent.

The business, under the control and management of Mrs. Hodgkinson, assisted by her son and daughter, was successful.

Mr. Hodgkinson's spare moments from business were now entirely devoted to reading any standard works on science which he could procure. The works of Simpson, Emerson, and Dealtry contributed greatly to his knowledge. He read these authors with earnestness and fidelity, and was wholly indebted to them for his knowledge of the higher departments of mathematical research. Many of the self-taught men of the last and the beginning of the present century have expressed their obligations to Thomas Simpson and William Emerson. Their works, whatever prejudice may think or say to the contrary, were the best standard works of the age; and it may be affirmed that the scientific literature of the eighteenth century is accurately and faithfully reflected from the pages of the weaver of Market Bosworth, Thomas Simpson, and the Hurworth village schoolmaster, William Emerson. These humble but highly gifted men were more catholic in their writings than are the authors of the present age. They wrote to instruct the mass of mankind, but the writers in these days labor for a special purpose, which is limited in its operation: they write only to supply the daily routine of the school, without casting a single thought beyond its boundary.

The late Rev. Robert Murphy, a Cambridge mathematician of distinguished eminence, speaks of Thomas Simpson as an analysist of first-rate genius. (See "Murphy's Equations.") M. Clairaut, when in England, paid Simpson a visit at Woolwich, in order to compare his own investigations on the motion of the moon's apogee with the investigations of Simpson on the same subject. This fact alone shows the high position in which Simpson stood in the estimation of the most eminent mathematicians of Europe.

In consequence of his ardent love for scientific pursuits, Mr. Hodgkinson became acquainted with the most gifted men then living in Manchester. Dr Dalton, Holme, Henry, Ewart, Sibson, Johns, Fairbairn, were among the scientific friends with whom he could freely converse on subjects which possessed a mutual interest. In his mathematical reading he sought and obtained the help of Dr. Dalton, who was then a private teacher of mathematics in Manchester. He became one of Dalton's pupils, and read with him the works of Lagrange, Laplace, Euler, and Bernoulli, whose writings were now engaging the attention of the best and foremost mathematicians of England. These authors had been instrumental in producing a great change in the mathematical sciences at Cambridge; their investigations were models of elegant algebraical demonstration, both with regard to symmetry of notation and subject-matter of inquiry. The friendship of Dalton and Hodgkinson, cemented by genial minds and kindred pursuits, continued uninterruptedly till the death of Dalton. Though each of these men had his distinctive field of labor, yet each could hold converse with the other on their respective researches, and Mr. Hodgkinson entertained through life a profound respect for the high character and great chemical discoveries of his friend. The extent of his mathematical reading at this period may be estimated by referring to his paper entitled "On the Transverse Strain and Strength of Materials," printed in the fourth volume of this society's memoirs.

HIS CHARACTER.

The late Professor Hodgkinson, like a true philosopher, was satisfied with a small but adequate competency, and, retiring from business at an early period, he devoted a long life and rare mental gifts to the development of science. And it is a pleasing reflection that while many men very eminent in the history of science have had to wait a long time before their discoveries have been recognized and adopted, Mr. Hodgkinson had the unusual pleasure of seeing the fruits of his labors appreciated and applied to the construction of great practical engineering enterprises. The youthful days of Mr. Hodgkinson were not

marked by precocious talents and wonderful achievements; still he possessed, even in youth, a quick perception of the relations of abstract magnitudes, and manifested, like Newton and Stephenson, a strong propensity for making sun-dials.

Manhood developed in him a profound intellect, a highly cultivated intelligence, unwearied perseverance, and a kind and an affectionate heart. He discharged every relation of life with fidelity, and has left behind him a name great in the annals of science, reflecting every manly virtue, and unsullied by any act of meanness. He was, however, very jealous of the products of his own mental labors, which he regarded as personal property, and was also equally just in the use of the mental property of other cultivators of science, as he would not appropriate the conclusions of any man without due acknowledgment

If he did entertain any hostile feeling, it was against those who, as he conceived, were unscrupulous in their appropriation of the fruit of other men's brains. His sense of justice would not allow him to show the slightest sympathy with this class of offenders.

The efficiency of Mr. Hodgkinson's lectures at University College, and of his oral instruction generally, was somewhat circumscribed by his hesitancy of speech. This peculiarity interfered with his usefulness as a speaker and teacher, and rendered his explanations of subjects, even those with which he was most familiar, somewhat tedious to the student. And it is perhaps one of the greatest evidences that can be recorded of the power of his mind, that he was thought worthy, in spite of his embarrassed address and slowness of speech, to be installed in a professorial chair in one of the leading scientific colleges of the kingdom. As a relaxation from severe mental toil, he cultivated a taste for general literature and the architecture of the middle ages. Of late years he frequently travelled, both on the continent and in the British empire, to examine those stupendous cathedrals and other public buildings which adorn western Europe, and which testify to the good taste, piety, and intellectual culture of the age in which they were built. He was fond also of investigating the remains of antiquity. And, what is valued above all by a man of science, he enjoyed the friendship and esteem of his contemporaries, who were able to estimate his worth, appreciate his talents, and apply his discoveries to useful purposes. The most eminent engineers of the age placed unbounded confidence in the results of his experiments, believing them to be faithfully recorded and accurately reduced to meet the requirements of mathematical formulæ. As a confirmation of this, it may be stated that the engineers' pocket and text-books of the present time are full of Hodgkinson's formulæ for calculating the strength and deflection of pillars and beams.

Mr. Hodgkinson was twice married, but without issue in each case. His first wife was Miss Catherine Johns, daughter of the respected Rev. William Johns, a distinguished member of this society, who contributed an interesting paper to its memoirs, entitled "Remarks on the Use and Origin of Figurative Language," (vol. ii, new series.) His second wife was Miss Holditch, daughter of Henry Holditch, esq., captain in the Cheshire militia. This lady, who is now left to mourn her loss, devoted her powers to comfort and sustain her husband when his health and memory would not admit of his having recourse to his favorite pursuits. Of late his great mental powers became prostrate, and his memory failed so much that it was obvious to his friends the time had arrived when his faculties required repose. In this state of mental lassitude the services of Mrs. Hodgkinson were of great value to him. It is not unusual with men whose mental powers have been overstrained by excitement and hard labor that the desire for intellectual activity does not cease when the physical power necessary to sustain it is feeble. Mr. Hodgkinson was the subject of this painful experience: the desire for mental activity continued unabated to the last; and it was only a few months before his decease that he was engaged in arranging

his papers, with a view to publish them, so that they might be more accessible to engineers than they now are in the volumes of learned societies.

Mr. Hodgkinson's religious emotions were silent, devotional in the highest sense—not sectarian; they were strictly confined to the channel between his Maker and his own soul. And in this way they were purified by the truth from heaven, bearing the precious fruit of meekness, charity, and implicit confidence in Him who is all and sustains all. His religion was the arbiter of his life, the judge of the many and important obligations between God, his fellow-man, and himself. His end was peaceful, and he has left a name marked by strict integrity, which will be well remembered in the walks of science for ages yet to come.

Let us now pass on to notice more in detail the works of Mr. Hodgkinson, which have raised him to a good degree among his contemporaries, and will also be the introduction to future thinkers in the same field of labor which he successfully cultivated.

"On the Transverse Strain and Strength of Metals," (read March 22, 1822.)

The objects aimed at in this paper are, as stated by the author, to unite, in a general formula, the commonly received theories in which all the fibres are conceived to be in a state of tension; and next, to adapt the investigation to the more general case, where part of the fibres are extended and part compressed, and to seek experimentally for the laws that regulate both the extensions and compressions. The manner in which these objects have been sought and developed is a model worthy of every commendation, of clear, sound, geometrical reasoning and refined artifice. And the data necessary to give practical effect to the various analytical formulæ have been obtained from experiments, than which none have been recorded with greater fidelity and less contortion to meet the demands of particular theories. No painstaking or expense was considered too great to make the results of the experiments successful and trustworthy, so that the engineer and philosopher alike could place implicit reliance upon them. In these experiments there is recorded, for the first time, an element which has furnished a theme for many animated discussions of late years among philosophers and practical engineers, and which became an important object of research in all Mr. Hodgkinson's subsequent experiments, viz., *set*, or the difference between the original position of a strained body and the position which it assumes when the strain is removed.

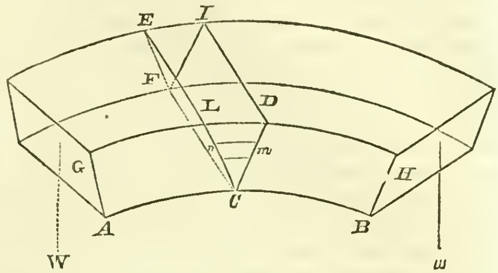
This point, which is full of interest and important consequences to the practical man, cannot now be discussed. On examination I believe that I shall be borne out in the statement that, notwithstanding the number of books which have been written during the last 30 years on the strength and strain of materials, some of a more ambitious kind, and others having the humbler object of being useful in communicating information to the artisan, still there is none from which a clearer and more satisfactory exposition of this subject can be gathered than from the paper above referred to by Mr. Hodgkinson, in the volume for 1822. The Tuscan philosopher, Galileo, has the merit of first propounding a theory of the strength of materials, and applying the unerring principles of geometry to the computation of the strength of beams of given dimensions. With Leibnitz originated the idea of the force of extension of a fibre being proportional to its distance from the lower side of a bent beam. James Bernoulli first suggested the notion (for it never assumed any other shape in his mind) of a *neutral line* in the section of rupture. But to the late Professor Hodgkinson belonged the merit of giving practical effect, in this paper, to the happy suggestion of Bernoulli, by showing, both theoretically and experimentally, the true method of determining, in the section of fracture, the exact position of the neutral line, and of calculating the strength of the beam.

In order, then, to show more clearly the steps taken by Mr. Hodgkinson in

the establishment of sound practical views of this subject, it will be necessary to give a brief exposition, by reference to diagrams, of the history of the section of fracture.

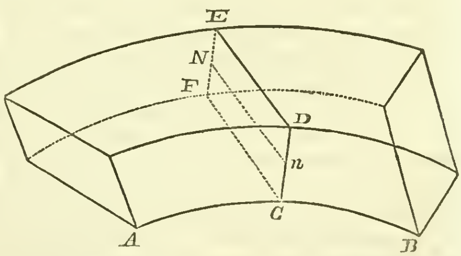
Every beam of material is supposed to be composed of an indefinite number of parallel filaments in the direction of its length, and the breaking of the beam necessitates the breaking of each of the filaments of which it is composed. Suppose a beam AB, placed on the fulcrum CF, to be broken at the section CDIEFL by the weights W and w, suspended from the points G and H.

Fig. 1.



The theory of Galileo assumes the beam to turn about the fulcrum CF, and each of the filaments (nm) in the section of fracture CLD to sustain an equal force. This hypothesis implies the incompressibility and extensibility of the material. Leibnitz, the great rival of Newton, assumed the beam to turn about the fulcrum CF, as did Galileo, but assumed, what experiment has confirmed, the force of each filament in the section of rupture to vary in proportion to its distance from the fulcrum CF. This theory implied the incompressibility and extensibility of the material. James Bernoulli, to whose labors science is under great and varied obligations, in reviewing the theories of Galileo and Leibnitz, felt convinced of their incorrectness, and that of course they could have no favorable response from the voice of nature. He assumed, or rather suggested, the beam (fig. 2) to turn about the line Nn, which is now commonly called the neutral line, and the filaments above Nn to be extended, and those below Nn to be compressed. He supposed, with Leibnitz, the force of each filament to be proportional to its distance from Nn, the neutral line.

Fig. 2.



This theory clearly indicates the compressibility and extensibility of the material, and so far agrees with all recorded experience. Bernoulli never pushed this idea beyond a suggestion, and it remained unfruitful in consequences till Mr. Hodgkinson, in this paper, followed it up, and fixed, for the first time, the exact position of the neutral line, and made it subservient to the computation of the strength of a beam of given dimensions. We can scarcely exaggerate the importance of this step, as it forms the connecting link between the correct assumption of Leibnitz and the complete theory of the transverse strength of beam. Without the position of the neutral line, the section of fracture appeared dark and uncertain, and we now wonder that the determination of this line had escaped the penetration of Professor Barlow and others who had examined the subject. The opinions here expressed are founded upon the results obtained by reading the works of the best authors previous to 1822.

Dr. Robison, Playfair, Barlow, Dr. O. Gregory, and Sir J. Leslie are sufficiently known in the walks of science to justify the assertion that their works on elementary subjects represent the true state and progress of the knowledge of the strength and strain of materials. Playfair's "Outlines of Natural Philoso-

phy," a work of great merit and well adapted for the time in which it appeared, contains only the following paragraph on the subject of the *neutral line :*

"But it is also said that a tube of metal has been found to support a greater transverse strain than a solid cylinder of the same diameter; or that a cylinder, when bored in the direction of the axis and a considerable part taken away, was stronger than before." "This must undoubtedly arise from a change taking place in the position of the fulcrum or hinge round which the fracture is made. In the case of a cylinder, and indeed of all solids, the fulcrum is not the mere outward edge, but a point in the interior, on the one side of which the fibres are elongated and on the other crushed together. The point, then, which serves as the fulcrum, will be found within the solid, at a greater or less distance, as the parts resist lengthening more than crushing. The consequence of this is that when the centre of gravity and the fulcrum are brought nearer to one another, the strength of the beam or bar is diminished. When the heart of a solid mass is cut out, as is supposed of the cylinder, the fulcrum, or the axis of the fracture, is perhaps kept nearer to the surface than when the whole is a solid mass. This, at least, seems to be the most probable account that can at present be given of a phenomenon not a little paradoxical and not yet sufficiently examined." (See Playfair's "Outlines," vol. i, p. 153.) Professor Barlow, in his "Essay on the Strength and Stress of Timber," published in 1817, at page 32, shows in an admirable manner the inaccurate views of Dr. Robison respecting the determination of the neutral line, but fails entirely to remedy the defect. Barlow proposes, what is equally ineffective, to fix the position of the neutral line, by supposing the moments of the extended fibres about the neutral axis to be equal to the moments of the compressed fibres about the same line." Sir J. Leslie, in his "Elements of Natural Philosophy," published in 1823, at page 234, states that "in the case of a horizontal beam supported at both ends, but depressed by its own weight, the upper surface becomes concave and the under surface convex. The particles of the upper surface are therefore mutually condensed; in a certain intermediate curve the particles are not affected longitudinally, though bent from their rectilineal position. This curve of neutral action may be assumed in the middle of the beam." Dr. O. Gregory, in his "Mechanics," published in 1826, at page 122, vol. i, states, in reference to the subject of the neutral line, "There is, moreover, the consideration that, when a beam deposited horizontally, or nearly so, is ruptured by a vertical pressure, a horizontal stratum, from end to end, is compressed, and the other portion extended or stretched, the thin lamina between these two being regarded as a neutral axis. This, again, is a curious topic of inquiry." This author gives several theories of the strength of materials from Venturoli, not any one of which contains the correct determination of the neutral line. From these quotations of the best informed writers, are we not justified in the inference that to the late Professor Hodgkinson belonged the merit of first accurately conceiving the true mechanical principle by which the position of the neutral line in the section of fracture could be determined? He did this by equating the forces of extension with the forces of compression—a method which is now universally adopted in computing the strength of beams. This method of fixing the neutral line, like all new methods, advanced to its present position by slow degrees; but, after many conflicts and discussions, the triumphant declaration of Professor Barlow, at the British Association of 1833, established this great principle, which was first conceived by Mr. Hodgkinson, who, single-handed, had maintained his position against the formidable powers of acknowledged authorities. Professor Barlow, in his report "On the Present State of Our Knowledge Respecting the Strength of Materials," printed in the third volume of the reports of the British Association for the Advancement of Science, 1833, very justly alludes to this subject, and states as follows: "Mr. Hodgkinson, however, in a very ingenious paper read at the Manchester Philosophical Society in 1822, has pointed out an error

in my investigation, by my having assumed the momentum of the forces on each side of the neutral axis equal to each other, instead of the forces themselves. This paper did not come to my knowledge till the third edition of my essay was nearly printed off, and the correction could not then be made." The Rev. Dr. Whewell, in his "Analytical Statics," refers to this paper, and gives the investigation of the neutral line on the same principle as that adopted by Mr. Hodgkinson, who always maintained that "we could see no cause why it should be rejected, especially since it seems to us to be everywhere consistent and just." (See Manchester Philosophical Society's Memoirs, vol. iv, p. 241.) It appears that his friend, Dr. Dalton, took great interest in the deductions of this paper, and discussed them freely with him as he proceeded with his experiments, which will ever be regarded as marking an epoch in the subject of the strength of materials. Indeed the theoretical investigations of this paper, though new and important, form only a small portion of its merits. The experiments recorded in it established the laws, "that the extensions of the fibres of a bent beam were proportional to the forces during the early stages of flexure; but as the extensions arrived nearer to fracture they increased faster than the forces," and, "that so long as the forces are moderate and are applied in the direction of the fibres, the compressions will be as the forces; but when the beam becomes bent the fibres, being then crushed, offer a feeble resistance to the force." These results were obtained direct from the unerring voice of nature. The first of these laws was announced by Dr. Robison, as a general law of nature, on the simple authority of a few experiments on the slips of gum caoutchouc and the juice of the berries of the white bryony, of which a single grain will draw to a thread two feet long, and again return to a perfectly round sphere. (See "Manchester Memoirs," vol. iv, p. 252.)

"On the Forms of the Catenary in Suspension Bridges," (read February 8, 1828, vol. v.)

The chain bridge at Broughton, Manchester, which broke down by a troop of soldiers marching over it, and the celebrated Menai suspension bridge, built by Telford, had stimulated inquiries respecting the best form of such structures. These inquiries, naturally enough, led to a reconsideration of the catenary, a curve the properties of which, under given conditions, were first discovered by James Bernoulli. (See Leslie's "Geometry of Curved Lines.")

In this paper a great degree of generality is given to the catenarian curve. After the known properties of the common catenary are clearly investigated, the formulæ are then applied with great ability to determine the form of suspension bridges when the *weight of catenarian chain, the weight of the roadway*, and *the weight of the suspension rods* are taken into account. The introduction of these complex, though necessary, elements into the question led to the formation of the following difficult and comprehensive differential equation:

$$\frac{adx}{dy}=bz+cy+e\int xdy \quad . \quad . \quad . \quad . \quad (A,)$$

where x, y are the current co-ordinates of a point in the curve, and z the length of the curve from this point to the lowest point. The explanation of the constants a, b, c, e is as follows:

a=the tension of the curve at its lowest point.

b=the weight of a unit of length of the curve.

c=the weight of a unit of length in the roadway, which is supposed to be divided transversely into separate parts, and may include any weight uniformly distributed over it, with that of the suspension rods below the horizontal line.

e=the weight of a unit of vertical surface in the suspending rods, the rods being here supposed to be uniformly distributed, and indefinitely near to one another, and therefore reckoned as a uniform surface.

This differential equation, under given conditions of the constants, is treated in this paper in a very able manner, showing great command over the resources of modern analysis, and facility in the use of the varied artifices employed in the integration of differential equations. The results arrived at have been referred to by the ablest writers of the age, Dr. Whewell and the Rev. Canon Moseley—by the former in his "Analytical Statics," where the solution of equation (A,) as given by Mr. Hodgkinson, occupies a distinguished place; by the latter in his "Engineering and Architecture," in which the labors of our late friend are honorably mentioned:

"This problem appears first to have been investigated by Mr. Hodgkinson in the fifth volume of the 'Manchester Memoirs;' his investigation extends to the case in which the influence of the weights of the suspending rods is included." After such testimony it would be presumption on my part to enter more into detail on this paper. To a modern student, however, the notation and procedure adopted may possibly contrast unfavorably with the notation and procedure which characterize the elementary works of the present day. To such student, if there be any, I would suggest that in forming an opinion on a paper like this, written more than 30 years ago, it would be unfair to exclude the comparison of the state of mathematical and physical science at that period with the present. It must be remembered that Lord Brougham and his coadjutors in a great work have done much to popularize and spread amongst their countrymen a knowledge of the arts and sciences. These interesting subjects can now be read as they have come from the hands of Euler, Lagrange, and Laplace, by means of cheap publications, which are within the reach of the humblest artisan. In consequence of this, it is not high praise to state that questions in mathematics which could have been accomplished with difficulty 30 years ago can now be readily solved by the present methods, which are now extensively known amongst the youth of all ranks in society through the warming stimulant of competitive examinations. In this statement I am anxious not to be misunderstood, and to guard against giving an opinion as to the question "Has mathematical power increased in the degree commensurate with the increase of mathematical learning?" This will form a nice question for the future historian of the inductive sciences to determine. I may, however, express my views on this debatable question so far as to say that I have but little confidence in the products of unnatural growth of any kind.

There is a very marked difference in the mathematics of this and his former paper "On the Strength of Materials." The great battle between the *dots* and the *d's* had been fought at Cambridge University with earnestness on both sides, and, chiefly through the invincible courage and inexhaustible armory of Woodhouse, Peacock, Babbage, and Herschel, the *d's* of Leibnitz wrested the victory from the *dots* of Newton. The effects of this victory, which has produced a great change in the mathematical literature of this country, are clearly seen in this paper, the principles investigated in which are applied to the numerical computation of the strength and strains of the Menai and Broughton suspension bridges.

"Theoretical and Experimental Researches to ascertain the Strength and best Forms of Iron Beams," (read April 2, 1830.)

Whether we consider the theoretical exposition of the section of fracture, or the faithfully recorded experiments and their practical deductions, we must regard this paper as the most valuable and original contribution to the history of the strength of materials which this century can boast. There is no work in our language on the same subject which contains sounder theoretical views, and there is none which can be more practical than it has been to meet the demands of the engineers and the architect. From the theoretical expositions here given of the neutral line, the experiments to determine the strongest beam were devised and successfully carried out.

The result was the discovery of the celebrated "Hodgkinson's Beam," that is, the strongest beam which can be made from a given weight of material and a given length and depth of beam. George Stephenson, who was at this time chief engineer to the Manchester and Liverpool Railway Company, took great interest in these experiments, and he was frequently present when they were made. Several pages are devoted again to the subject of the neutral line, indicating, from the manner of its discussion, that the subject was not at this time clearly fixed in the minds of the foremost investigators; and no one can read these pages, and the views of Professor Barlow, without feeling convinced that the learned professor has scarcely done full justice to Mr. Hodgkinson in reference to the fixing of the neutral line in the section of fracture. The statement of Professor Barlow, in his report to the British Association, and in his essay "On the Strength of Materials," would lead to the conclusion that Mr. Hodgkinson had only rectified a small error into which he, Barlow, had inadvertently fallen. This is not a complete statement. Mr. Hodgkinson did much more than correct a slight error in an adopted theory; he showed the fallacy of the theory which it appears Professor Barlow had obtained from M. Duleau, a distinguished French writer. There can be no doubt that Mr. Hodgkinson was the first to give the correct theory of fixing mathematically the position of the neutral line. Mr. Hodgkinson's paper was published in 1822, and we find, in 1824, Dr. Whewell, in his "Mechanics," stating, "I would gladly have given a section on the strength and fracture of beams had there been any mode of considering the subject which combined simplicity with a correspondence to facts. The common theory, which supposes the material incapable of compression, is manifestly and completely false; and though Mr. Barlow's experiments and investigations give us much information, they do not appear to lead to any conclusions sufficiently general and simple to authorize us to present the subject as an elementary one." (See Preface, page xii, Whewell's "Mechanics," 1824.) It is obvious that the learned professor had not seen Mr. Hodgkinson's paper at this time, or he would have given, without doubt, in this place the same chapter which he published in his "Analytical Statics" in 1833.*

The first series of experiments in this paper show that in cast iron the extensions and compressions from equal forces are nearly equal. Tredgold asserted that the same force which destroyed the elasticity of a body by tension would destroy it by compression. The next two experiments disprove this assertion, and show that the resistance to compression in cast iron is greater than to extension. This discovery is important, and modified considerably the best constructed cast-iron beams of this period. The succeeding experiments, which are many and carefully recorded, were devised for the purpose of extending the consequences of this practical discovery. And I shall here avail myself of the Rev. Canon Moseley's concise and able exposition of the experiments and reasonings of Mr. Hodgkinson by which he established the best form of cast-iron beam:

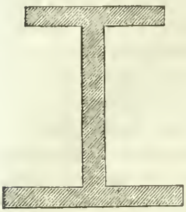
"Since the extension and the compression of the material are the greatest at those points which are most distant from the neutral axis of the section, it is evident that the material cannot be in the state bordering upon rupture at every point of the section at the same instant, unless all the material of the compressed side be collected at the same distance from the neutral axis, and likewise all the material of the extended side, or unless the material of the extended side and the material of the compressed side be respectively collected into two geometrical lines parallel to the neutral axis—a distribution manifestly impossible, since it would produce an entire separation of the two sides of the beam.

"The nearest practicable approach to this form of section is that represented in the accompanying figure, where the material is shown collected in two thin

* I have Dr. Whewell's authority, in a letter which I received from him a few days ago, in stating that he had not seen Mr. Hodgkinson's paper when he wrote his "Mechanics" of 1824.

but wide flanges, but united by a narrow rib. That which constitutes the strength of the beam being the resistance of its material to compression on the one side of its neutral axis and its resistance to extension on the other side, it is evidently a second condition of the strongest form of any given section, that when the beam is about to break across that section by extension on the one side, it may be about to break by compression on the other. So long, therefore, as the distribution of the material is not such as that the compressed and extended sides would yield together, the strongest form of section is not attained. Hence it is apparent that the strongest form of the section collects the greater quantity of the material on the compressed or the extended side of the beam, according as the resistance of the material to compression or to extension is the less. Where the material of the beam is cast iron, whose resistance to extension is greatly less than its resistance to compression, it is evident that the greater portion of the material must be collected on the external side.

Fig. 3.



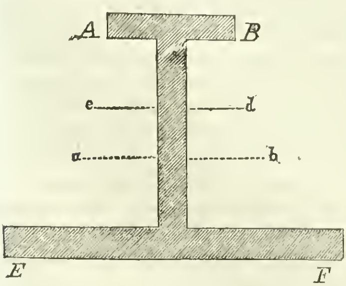
"Thus it follows, from the preceding condition and this, that the strongest form of section in a cast-iron beam is that by which the material is collected into two unequal flanges joined by a rib, the greater flange being on the extended side, and the proportion of this inequality of the flanges being just such as to make up for the inequality of the resistances of the material to rupture by extension and compression respectively. Mr. Hodgkinson, to whom this suggestion is due, has directed a series of experiments to the determination of that proportion of the flanges by which the strongest form of section is obtained.

"The details of these experiments are found in the following table:

Number of experiment.	Ratio of the section of the flanges.	Area of whole section in square inches.	Strength per square inch of section.
1	1—1	2.82	2368
2	1--2	2.87	2567
3	1—4	3.02	2737
4	1—4.5	3.37	3183
5	1—5.5	5.0	3346
6	1—6.1	6.4	4075

"In the first five experiments each beam broke by tearing asunder of the lower flange. The distribution by which both were about to yield together—that is, the strongest distribution—was not, therefore, up to that period reached. At length, however, in the last experiment, the beam yielded by the compression of the upper flange. In this experiment, therefore, the upper flange was the weakest; in the one before it the lower flange was the weakest. For a form between the two, therefore, the flanges were of equal strength, to resist extension and compression respectively, and this was the strongest form of section. In this strongest form the lower flange had six times the material of the upper. It is represented in the accompanying figure. In the best form of cast-iron beam or girder used before these experiments, there was never attained a strength of more than 2,885 pounds per square inch of section. There was, therefore, by this form a gain of 1,190 pounds per square inch of the section, or of two-fifths the strength of the beam." (See Moseley's "Engineering and Architecture," art. 411.)

Fig. 4.



The Rev. Canon Moseley further observes on this point, "It is only in cast-iron beams that it is customary to seek an economy of the material in the strength of the section of the beam; the same principle of economy is surely, however, applicable to beams of wood."

This victory over the material foe is entirely Mr. Hodgkinson's own; and, using the language of the president of the British Association at Manchester, 1861, there is no one to divide the honor of this useful achievement with him. The Hodgkinson beam is really what its name would imply, as he originated the conception and pursued it with judgment and industry until the best form of beam was fully determined. This beam has been the pole star for engineers and builders during the last 20 years, a period in which construction of all kinds has been in great demand, and in which the ingenuity and skill of the constructor has been confronted with many and formidable difficulties. Railways, ship-building, and public works of various kinds have opened out new channels for the application of cast and wrought iron; and when this material is placed in new and untried positions, it is no little point which is gained when its tensile and crushing strength is determined, and the best form investigated by which the safety of large structures is secured. This was the life-work of Professor Hodgkinson.

It is a great thing, which no man of science lightly appreciates in these days of mental activity, for a man to point to a useful discovery and claim it as his own without a rival, to say to himself, (his own precious reward,) "I drew it forth from the dark chaos in which it had been entombed for ages to the light of day, and now I leave it as a legacy to my countrymen, trusting that the chance of calamities such as that which happened at Hartley Colliery, where 200 men lost their lives by the breaking of a cast-iron beam, may be diminished, if not entirely obviated." In this paper Mr. Hodgkinson acknowledges his deep obligations to the liberality of his friend Mr. Fairbairn, in procuring for him the beams whereon to experiment.

The contributions of Professor Hodgkinson to the "Reports" and "Sections" of the British Association were numerous and important. In proof of this it is only necessary to refer to the opening address of the president, Professor Sedgwick, at the meeting at Edinburgh in 1834: "The association may claim some credit for having brought into general notice the ingenious investigations of Mr. Hodgkinson of Manchester."

In the Report of 1833 there are two papers by Mr. Hodgkinson:

1. "On the Effect of Impact of Beams."
2. "On the Direct Strength of Cast Iron."

In the Report of the British Association of 1834, we find an extended inquiry into the collision of imperfectly elastic bodies. After alluding to Newton's labors, as recorded in the "Principia," Mr. Hodgkinson proceeds to describe the methods by which his experiments were made, and derives from them the following non-clusions:

1. All rigid bodies are possessed of some degree of elasticity, and among bodies of the same nature the hardest are generally the most elastic.

2. There are no perfectly hard inelastic bodies, as assumed by the early and some of the modern writers on mechanics.

3. The elasticity, as measured by the velocity of recoil divided by the velocity of impact, is a ratio which (though it decreases as the velocity increases) is nearly constant when the same rigid bodies are struck together with considerably different velocities.

4. The elasticity, as defined in 3, is the same whether the impinging bodies be great or small.

5. The elasticity is the same, whatever be the relative weights of the impinging bodies.

6. On impacts between bodies differing very much in hardness, the elasticity with which they separate is nearly that of the softer body.

7. In impacts between bodies whose hardness differs in any degree, the resulting elasticity is made up of the elasticities of both, each contributing a part of its own elasticity in proportion to its relative softness or compressibility.

The following rule, given by Mr. Hodgkinson, agrees remarkably well with the results of experiments:

Let ε = the elasticity of A } as determined by A striking against A, &c.
ε' = " B }

m = modulus of elasticity of A } as determined by extending the material
m' = " B } in the ordinary way.

Then the elasticity of A against $B = \dfrac{\varepsilon m' + \varepsilon' m}{m' + m}$.

This paper concludes with a table of elasticities of 60 various substances used in the construction of buildings, &c.

The Fifth Report of the British Association contains a paper on the "Impact of Beams."

The author has deduced from the experiments the following laws:

1. If different bodies of equal weight, but differing considerably in hardness and elastic force, be made to strike horizontally with the same velocity against the middle of a heavy beam supported at its ends, all the bodies will recoil with velocities equal to one another.

2. If, as before, a beam be struck horizontally by bodies of the same weight, but different in hardness and elastic force, the deflection of the beam will be the same, whichever body be used.

3. The quantity of recoil in a body, after striking against a beam as above, is nearly equal to what would arise from the full varying pressure of a perfectly elastic beam as it recovered its form after deflection.

4. The effects of bodies of different natures striking against a hard, flexible beam seem to be independent of the elasticities of the bodies, and may be calculated, with trifling error, on a supposition that they are inelastic.

5. The power of a uniform beam to resist a blow given horizontally is the same in whatever part it is struck.

6. The power of a heavy uniform beam to resist a horizontal impact is to the power of a very light one as half the weight of the beam, added to the weight of the striking body, is to the weight of the striking body alone.

7. The power of a uniform beam to resist fracture from a light body falling upon it (the strength and flexibility of the beam being the same) is greater as its weight increases, and greatest when the weight of half the beam, added to that of the striking body, is nearly equal to one-third of the weight which would break the beam by pressure.

There can be but one opinion as to the importance of these deductions, direct from the voice of nature, made, as they were, at a time when such an appeal was by no means common.

There are several interesting problems on impact, of a high mathematical character, solved in this paper. In these inquiries Mr. Hodgkinson is very particular in acknowledging his many obligations to his friend Mr. Fairbairn, engineer, of Manchester, to whose labors and liberality practical science is deeply indebted.

We now pass on to notice his contributions to the transactions of the Royal Society.

In the Philosophical Transactions for 1840 there is an extensive inquiry by Mr. Hodgkinson, "On the Strength of Pillars of Cast Iron and other Materials."

The object of this inquiry is to supply a desideratum in practical mechanics, which had been pointed out by Dr. Robison and Professor Barlow. In order to accomplish this it was necessary to institute a series of expensive experiments more varied and extensive than any which had hitherto been made public. The

subject was mentioned to Mr. Fairbairn, who at once, with his characteristic liberality, supplied his friend with ample means for investigating experimentally the strength of cast-iron pillars. For this paper the council for the Roya Society awarded Mr. Hodgkinson the royal medal as a mark of their appreciation of his labors, the value and importance of which are confirmed by every ngineer's pocket-book in Europe during a period of 20 years.

The inquiry is naturally divided into two parts, viz., long pillars and short pillars.

LONG PILLARS.

The first object was to supply the deficiencies of Euler's theory of the strength of pillars, if it should appear capable of being rendered practically useful, and if not, to endeavor to adapt the experiments so as to lead to useful results. For this purpose solid cast-iron pillars were broken, of various dimensions, from five feet to one inch in length, and from half an inch to three inches in diameter. In hollow pillars the length was increased to seven feet six inches, and the diameter to three inches and a half.

With pillars of cast-iron, wrought iron, steel, and timber, whose length is upwards of 30 *times their diameter, the strength of those with flat ends is three times as great as those with rounded ends.*

Experiments were next made upon pillars with one end flat and the other end rounded, and the result is summed up in the following interesting and important law:

With pillars of the same diameter and length, both ends rounded, one end rounded and the other flat, and both ends flat, their strengths are as 1, 2, 3, *respectively.*

When the pillars were uniform, and the same shape at both ends, the fracture took place in the middle. This was not the case when one end was flat and the other rounded, as the fracture then took place at about one-third of the length from the rounded end. Hence, in these pillars, the metal may be economized by increasing the thickness in the point of fracture.

It follows, from Euler's theory, that the strength of pillars to bear *incipient flexure* is directly as the fourth power of the diameter, and inversely as the square of the length.

This incipient flexure was sought for by Mr. Hodgkinson without success, and he states his conviction that flexure commences with very small weights, such as could be of little use to load pillars with in practice. Although Mr. Hodgkinson was unable to find the point to which Euler's computations refer, still he has shown that Euler's formula is not widely from the truth when applied to the breaking point of the pillar. From a great number of experiments Mr. Hodgkinson deduced the following formula for pillars with rounded ends:

$D =$ diameter of pillar in inches.
$L =$ length of pillar in feet.
$W =$ breaking-weight in tons.

Then, $W = 14.9\dfrac{D^{3.76}}{L^{1.7}}$.

The above rule applies to pillars the length of which is 15 times the diameter and upwards. Perhaps not quite so low as 15 times the diameter in large pillars, as there is a reduction of the strength of such pillars, owing to the softness of the metal in large castings. This remark is significant, and gave rise to many interesting experiments at Portsmouth dockyard by the royal commissioners, conducted by Colonel Sir Henry James.

When the pillars are flat at the ends, the formula becomes

$$W = 44.16\frac{D^{3.55}}{L^{1.7}}.$$

This rule applies to pillars whose lengths vary from 30 to 121 times the diameter,

SHORT PILLARS.

In order to estimate the breaking-strength of short pillars, Mr. Hodgkinson considered the strength of the pillar to be made up of two functions.

1. To support the weight.
2. To resist flexure.

When the breaking-weight is small, as in long pillars with small diameters, then the strength of the pillar will be employed in resisting flexure. When the breaking-weight is one-half the pressure required to crush the pillar, one-half of the strength may be considered available to resist flexure, and the other half to resist crushing. And when the breaking-weight is so great as in the case of short pillars, it may be considered that no part of the strength of the pillar is applied to resist flexure. These two effects may be separated in all pillars by dividing the pillar into two portions, one of which would support the weight without flexure, and the other would support the flexure without crushing, to the extent indicated by the preceding formulæ.

Let $c =$ the force which would crush the pillar without flexure.

Let $\mathrm{P} =$ the utmost pressure the pillar would bear without being weakened by crushing.

$b =$ breaking-weight as calculated by the preceding formulæ.

$y =$ the actual breaking-weight of short pillars.

$$\therefore \frac{y}{b} = \frac{1}{\frac{b}{c}+\frac{3}{4}} \text{ where } \mathrm{P}=\frac{c}{4}.$$

The value of c is obtained from the formula

$$c = (\text{area of section}) \times 109{,}801 \text{ pounds.}$$

The reasoning by which the above formulæ are established is well deserving of attention, and shows that the author was a worthy successor of Euler, Lagrange, and Poisson in this important branch of practical science.

HOLLOW PILLARS OF CAST IRON.

Mr. Hodgkinson has shown that solid pillars with rounded ends and enlarged in the middle are stronger than uniform pillars of the same length and weight. This is proved to be the case in hollow pillars. The formulæ for the breaking-weight of hollow pillars, as derived from experiment, are as follows:

$w =$ breaking-weight in pounds.
$\mathrm{D} =$ external diameter in inches.
$d =$ internal diameter in inches.
$\mathrm{L} =$ length in feet.

For pillars with rounded ends,

$$w = 29074 \frac{\mathrm{D}^{3.76} - d^{3.76}}{\mathrm{L}^{1.7}}.$$

For pillars with flat ends,

$$w = 99318 \frac{\mathrm{D}^{3.55} - d^{3.55}}{\mathrm{L}^{1.7}}.$$

The strength of short hollow pillars must be calculated in the same manner as the strength of short solid pillars. These formulæ, derived from experiments made with great judgment and care, embody our present knowledge and practice of cast-iron pillars for bearing-purposes.

"The Power of Cast-iron Pillars to Resist Long-continued Pressure."

Mr. Hodgkinson has recorded in this paper several very interesting experiments on this subject. Two beams, rounded at the ends, six feet long and one inch diameter, were cast of Low Moor iron, No. 3. The first bore a weight of

1,456 pounds during a period of from five to six months, and then broke. The second broke with 1,500 pounds laid on immediately. From this experiment Mr. Hodgkinson inferred that time has but little, if any, influence on the strength of cast iron.

This inference seems, at least to me, to be theoretically correct. If the weight laid on the beam and its molecular forces be statically equal, the forces will remain in this state of equilibrium until the molecular forces are weakened by the influence of unequal temperature or other causes. Our knowledge, however, of this practical subject is indeed very limited. The inquiry would amply repay any one who has the ability, opportunity, and means to pursue it. Mr. Hawkshaw has made some admirable remarks on this subject in his evidence before the royal commissioners in 1847. (See Report, page 296.)

The opinion of experienced engineers appears to be that vibrations produced by continual impact and change of temperature affect the strength of iron to a greater extent than a continued strain, which preserves the molecules of the iron in the same fixed position. Mr. Rastrick, in his evidence before the commissioners, gives the result of an experiment made by a friend, bearing on this question, at Pontypool Iron Works. He hung a bar of iron, an inch square, up by one end perpendicularly, and contrived a small hammer to be continually hammering it; after a period of more than 12 months the bar of wrought iron dropped in two.

That the internal structure of iron becomes changed by continued vibrations is commonly believed by engineers of experience; but in what way this change is produced, both in speciality and magnitude, does not appear to be very definite. One thing, however, seems clear, viz., that wrought iron is more affected by vibrations than cast. The evidence given before the commissioners on this important question is very striking, and contains all the practical information which has been recorded or known on the subject. Mr. Fairbairn states "that if you take *any material* whatever, and destroy its original form, and repeat the changes, it is only a question of time how long it will be before it breaks."

According to my view, this statement from an engineer of so great experience should convince those whose duty leads them to the application of iron, timber, and stones to the erection of structures, the first characteristic of which is stability, of the existence and destructive nature of vibrations. Notwithstanding these views on the effect of continued vibrations, there are not wanting engineers of great eminence who think the subject of but little practical importance, however interesting it may be in a scientific and philosophical sense.

The late Robert Stephenson refers to the beam of a Cornish engine, and states that it receives a shock 8 or 10 times a minute equal to about 55 tons, during a period of 20 years, without the slightest perceptible change in its structure and strength.

The connecting-rod of a locomotive engine is another illustration in point: "One I know," says Mr. Stephenson, "which has run 50,000 miles, and received a violent jar eight times per second, or 25,000,000 vibrations, and yet there is not the slightest appearance of change in the strength of the connecting-rod."

The same distinguished engineer says, with respect to the question of the effect of vibrations on materials, "as to the change being produced in wrought iron, which is a very popular and almost universal theory now, I have not known one single instance in which I have traced it to its origin, where the reasoning is not deficient in some important link." On the whole, Mr. Stephenson attaches but little importance to the question of vibration in a practical sense.

Mr. Brunel, in answer to the question whether the internal structure of an iron beam becomes altered by a succession of slight blows at a low temperature, as in rails long used, railway axles, or springs of carriages, says, "I have turned my attention a good deal to this inquiry, and I have long acted on the assumption that iron is so changed; but I must confess that I have doubts as to the fact.

And I believe that if the subject were thoroughly examined it would be found that the different appearances shown by iron when broken arise from the combinations of the causes producing fracture as often as from any change in the texture of the material itself. This opinion was strengthened by various specimens of irons broken, some with a fibrous fracture by means of a slow heavy blow, and some with a crystalline fracture by means of a sharp, short blow. Mr. May refers to the case of a cast-iron beam of a steam engine, vibrating hundreds of thousands of times per annum, being as good at the end of 20 or 30 years as when first put up. In this case, though the strain has been in opposite directions, and constantly varying, still the vibrations have not weakened the beam. On the other hand he says, "I have seen a cast-iron gun absolutely broken across by many years' dropping pig-iron upon it."

In order to facilitate the calculation of the strength of short pillars, Mr. Hodgkinson has given the crushing strength of a great variety of timbers used in practice. The above is but a hasty and imperfect glance at this important paper, which appeared at the time when the railway system was developing itself by means of the application of cast and wrought-iron pillars to the construction of bridges, &c. No engineer who has in future to deal with this subject must omit the reading of this paper.

In the Philosophical Transactions for 1857 there is another paper by Mr. Hodgkinson on the strength of pillars. The object here is to confirm the conclusions of the first paper by means of larger experiments, made by an apparatus three times as great as the apparatus used on the former occasion. Having been unsuccessful in finding the weight producing incipient flexure, Mr. Hodgkinson devoted his attention to finding the breaking-weight, the deflection, and decrement of length produced by the weight laid on the pillars. The pillars with both ends rounded broke in one place, in the middle; but the pillars with both ends flat broke in three places—the middle and at each end. When one end was flat and the other rounded it broke at one-third the distance from the rounded end.

The formulæ in the former paper are here slightly corrected, as being more in accordance with the results of larger experiments.

Thus, in pillars whose ends are flat and well bedded, the formula becomes

$$w=42.347\frac{D^{3.5}-d^{3.5}}{L^{1.63}},$$

instead of

$$w=46.65\frac{D^{3.55}-d^{3.55}}{L^{1.7}},$$

as given in the first paper.

It is a matter of observation long recorded, both by Mr. Hodgkinson and other experimentalists, that the metal in large castings is not uniform in density, the density diminishing from the outside of the casting to the centre. Hence it was justly inferred that the crushing, tensile, and transverse strength of large castings would vary, being the greatest towards the outside and less towards the centre. In cast-iron pillars of $2\frac{1}{2}$ inches diameter, the crushing force varied from 39 tons per square inch outside to $33\frac{1}{2}$ tons per square inch centre. Mr. Hodgkinson discovered that the difference in the strength between the outside and centre of large castings is much less than in small ones. Colonel Sir Henry James found that the central part of bars of iron planed was much weaker to bear transverse strain than bars of the same size. By planing out three-fourth inch bars from the centre of two-inch square and three-inch square bars, the central portion was little more than half the strength of that from an inch bar.

The fall of the railway bridge over the river Dee at Chester, when several lives were lost, led Mr. Hodgkinson to investigate the position of the tension-rods, which were intended as auxiliary supports to the structure. The particu-

lars of this inquiry have escaped my memory, but I well remember that Mr. Hodgkinson showed, on the clearest geometrical evidence, that the position of the tension-rods was not only no additional support to the stability of the bridge but positively aided its downfall. This circumstance induced Mr. Stephenson to reconsider the construction of the bridge, and devise a new arrangement for these auxiliary supports. It was at this time, and in consequence of the accident above alluded to, that Mr. Robert Stephenson made the personal acquaintance of Mr. Hodgkinson, the friend of his father, the man to whom he had steadily looked as his authority and guide in the application of iron to railway purposes. When, therefore, Mr. Stephenson was engaged in the novel construction of the Conway and Britannia tubular bridges, he requested the assistance of his friend Mr. Hodgkinson in fixing the best form and dimensions of tubes. The experiments which were devised and carried out by Mr. Hodgkinson with a view to answer the above questions are recorded in the report of the royal commissioners appointed to inquire into the application of iron to railway structures.

Mr. Hodgkinson, by these experiments, sought—

1. To ascertain how far the strain upon a square inch at the top and bottom of the tube would be affected by changing the thickness of the metal, the other dimensions being the same.

2. To obtain the strength of similar tubes.

3. To find the strength of tubes of various forms of section in the middle, and to furnish means of judging of the proper proportions of the metal in the bottom, top, and sides of the tube.

4. To ascertain the relative strength of uniform tubes to bear a weight in all parts of their length; and whether tubes, tapering in thickness from the middle towards the ends, according to theory, would be equally strong in every part.

5. To obtain the resistance of the tubes, previously tried vertically, to bear a side pressure, with an intention to ascertain the effect of the wind upon a tube.

6. To ascertain the strength of small tubes of different forms of section to resist best a force of compression applied in the direction of their length.

7. To ascertain the resistance of wrought-iron plates to a crushing force in the direction of their length.

8. To determine the strength of tubes to sustain impact, with reference to riveting.

9. To determine, by bodies let fall upon tubes, the probable effect, if any, of trains rushing rapidly upon tubular bridges, to produce resilience, or springing up at the ends.

10. To determine the transverse strength of tubes stiffened in the top with cast iron, joined with wrought iron, to increase the resistance of the top to a crushing force.

These are important practical problems; and when the issue is considered, viz.: the continued stability of the Conway and Britannia tubular bridges, they required for their solution great skill in the subtilities and artifices of mathematical and experimental science. The answers which Mr. Hodgkinson obtained to the above problems were deemed by Mr. Stephenson to be so satisfactory as to enable him with confidence to build the tubular bridges.

A concise but clear exposition of these answers is given by Mr. E. Clark before the commissioners appointed to inquire into the application of iron to railway purposes. (See report, page 359.)

It was impossible that such assistance in the execution of a novel design could be lightly esteemed or inadequately appreciated by the great engineer. Hence, in the history of these tubular bridges, where Mr. Stephenson is anxious to record the merits of his assistants, he frankly acknowledges his deep obligations to the mathematical philosopher "*for devising and carrying out a series of experiments which terminated in establishing the laws that regulate the strength of tubular structures, in a manner so satisfactory that I was enabled to proceed with*

more confidence than I otherwise should have done." (See vol. i, p. 35, of the "Britannia and Conway Tubular Bridges," by E. Clark, esq.)

This declaration of Mr. Stephenson completely disarms all future praise or detraction with respect to the part which Mr. Hodgkinson took in the execution of the tubular bridges. It places him before the public in his right position as a most important contributor to the success of an enterprise which will represent the engineering skill of the present time, and will be the admiration of future ages. E. Clark, esq., who superintended the building of the tubular bridges, speaks in the highest terms of the importance of Mr. Hodgkinson's labors in fixing the proper dimensions of the bridges.

We are indebted to him also for nearly the whole of the mathematical calculations in reducing the experiments which were made into a form fit for application to a large structure. But we are also indebted to Mr. Fairbairn for a great portion of the practical construction of the bridges.

The answers given by Mr. Hodgkinson to his inquiries, and which rendered such signal service to the engineer in the execution of his novel design, are as follows:

1. The value of (f) the strain upon a square inch at the top or bottom of the tube is constant in material of the same nature, while it varies from 19, 14, to $7\frac{3}{4}$ tons when the thickness of metal varies from .525, .272, to .124 of an inch. The determination of (f) is the chief obstacle to obtaining a formula for the computation of the strength of tubes of every form.

The strength of the Conway tube was calculated to bear 1,084 tons when the value of (f) was taken at 8 tons, and the deflection about $15\frac{1}{2}$ inches in the middle.

2. The strength of similar tubes was somewhat lower than the square of their linear dimensions, being about 1.9 power instead of the square.

3. The tubes may be reduced in strength and thickness towards the ends, corresponding to the ratio indicated by theory, viz., that the strain at any point of the tube is proportional to the rectangle of the two parts into which that point divides the length of the tube.

4. The power of the tube to resist a vertical strain is to its power to resist a strain on its side, as from the wind, as 26 to 15, nearly.

5. The resistance of tubes to crushing follows the law of cast-iron pillars when the crushing force is not more than 8 tons per square inch. It appears, however, that cast iron was decreased in length double what wrought iron was by the same weight; but the wrought iron sunk to any degree with a weight of 12 tons per square inch, while cast iron required double the weight to produce the same effect.

6. The power of plates to resist buckling varies nearly as the cube of the thickness. Mr. Clark refers to this property as being most useful in the construction of the tubular bridge.

7. The tube bent by pressure had borne a deflection of five inches without serious injury; but its riveting was destroyed by repeated impacts deflecting it through less than one inch.

8. Resilience is perceptible, but very small.

9. The introduction of cast iron on the top of the tube would be attended with advantage in resisting the force of compression. Practical objections, however, of a serious nature prevented Mr. Stephenson from availing himself of the power of cast iron to resist compression. He thought it advisable to increase the thickness of wrought iron to resist compression, rather than use a combination of wrought with cast iron. It may be stated that Mr. Stephenson has used cast iron, for the purpose recommended by Mr. Hodgkinson, with success in tubes of smaller dimensions than the Conway tubes.

In 1847 Mr. Hodgkinson was appointed one of the commissioners to inquire into the application of iron to railway structures; and during the space of two

years the whole of his time and abilities were devoted to the subjects of this inquiry. The exertions, both physical and mental, which he made at this period for the advancement of engineering science were so great as materially to affect his health and prostrate his powers. Immediately after the publication of the commissioners' report in 1849, he sought the restoration of his exhausted faculties by a tour on the continent of Europe.

His labors for this commission are published in the report, and comprise 114 closely printed pages. The high importance of these labors may be, to some extent, inferred from the circumstance of the commissioners pointing them out for special notice. "Although we are aware that to point out the labors of individual members of the commission would be impossible, and that it may appear invidious to single out one for praise, we cannot resist the expression of our thanks to Mr. Hodgkinson for the zeal and intelligence with which he has carried out the remarkable series of experiments which are detailed in the appendix A to this Report, and which constitute a large proportion of those which have been already described." (See the Commissioners' Report, page 15.) Such, then, was the estimate of the labors of Mr. Hodgkinson by Lord Wrottesley, Professor Willis, Colonel James, Mr. Rennie, and Mr. Cubitt; and it has been amply confirmed by the engineering experience of the last 13 years.

The objects for which Mr. Hodgkinson sought in this inquiry were—

1. The determination of the longitudinal extensions and compressions of long bars of cast and wrought iron by weights varied by equal increments, up to that producing fracture.

2. The establishment of general formulæ connecting the longitudinal *extensions*, and *compressions*, and *sets* of cast iron with the forces producing them.

3. To determine the deflection of horizontal bars produced by various transverse pressures, and to compare the effects with those produced by impacts.

4. To determine general formulæ connecting the transverse pressure, the deflection, and set remaining after the pressure was removed.

If ε = elongation of a bar of cast iron one inch square and (l) inches long by a weight w,

$$\text{then } w = 13934040\frac{\varepsilon}{l} - 2907432000\frac{\varepsilon^2}{l^2}.$$

If d=compression of a bar of cast iron one inch square and (l) inches long by a weight w,

$$\text{then } w=12931560\frac{d}{l}-522979200\frac{d^2}{l^2}.$$

These formulæ were derived from the mean results of four different kinds of cast iron.

The mean tensile strength was found to be 15,711 pounds per square inch, and the ultimate extension was 1-600th of the length of the bar.

With respect to wrought iron, the extensions and compressions were found to be nearly proportional to the pressures producing them.

The extension is proportional to the pressure up to about 12 tons per square inch; after this the pressure is not proportional to the extension. The weight necessary to elongate a bar of wrought iron to double its length is 27,691,200 pounds, which is usually called the modulus of elasticity. One striking and important fact was elicited by these experimental researches, viz., cast-iron bars are decreased in length double as much as wrought-iron bars by the same pressure; but wrought-iron bars sink to any degree with little more than 12 tons' pressure per square inch of section, while cast-iron bars require three times the pressure to produce the same effect. It appears, also, that the tensile force of cast iron depends but little upon the form of the section, except so far as the form contributes to the better consolidation of the casting when in a fluid state.

The above results were obtained for the commissioners by the individual

labors of Mr. Hodgkinson himself, who alone is responsible for their accuracy, usefulness, and general adaptation to promote the ends of physical and engineering science; but there were other important results obtained by other members of the commission, to which it may not be deemed out of place to refer.

The experiments at Portsmouth dockyard, conducted by Colonel Sir Henry James, and the discussion of the results by Professor Willis and Professor Stokes, were also the work of the commissioners. And it would be no easy task to over-estimate the value of these labors, both on account of the novel nature of the experiments and the mathematical deductions to which they conducted when placed in the hands of Professor Stokes.

Colonel Sir Henry James and Captain Galton subjected cast-iron bars, placed between fixed supports, to 100,000 successive deflections, at the rate of four per minute, by means of a cam. When the deflections were one-third of the ultimate deflection, the bars were not weakened; when, however, the deflections were one-half of the ultimate deflection, the bars were broken with less than 900 depressions.

Professor Hodgkinson subjected cast-iron bars, firmly fixed between supports, to 4,000 continued impacts. When the blow was such as to deflect the bars one-third of their ultimate deflection, they resisted the concussion of 4,000 impacts without injury; but when the blow was such as to deflect the bars one-half of their ultimate deflection, no bar could resist 4,000 depressions. These results strikingly confirm each other.

Colonel James and Captain Galton caused a weight equal to one-half the breaking weight of the cast-iron bar to be drawn backwards and forwards from one end of the bar to the other. The bar was not weakened by 96,000 transits of the weight. No perceptible effect was produced in wrought-iron bars by 10,000 successive deflections, each of which was equal to that produced by half the breaking weight.

Professor Hodgkinson notices the following results which he obtained from his experiments on the impact of cast-iron bars:

All cast-iron bars of the same sectional area require the same blow to break them in the middle.

The deflections of wrought-iron bars produced by the striking ball were proportional to the velocity of impact; but in cast-iron bars the deflections were greater than the proportion to the velocity of impact.

The most striking and novel experiments, however, were those made by Colonel Sir Henry James and Captain Galton, at Portsmouth dockyard. These gentlemen constructed a large apparatus by which weights could be made to move over cast-iron beams placed horizontally between fixed supports, with velocities varying from 0 to 30 miles per hour. These experiments developed the singular fact, at variance with the impressions of the most eminent engineers, that a train passing over a bridge at a given speed will produce a greater deflection than that produced by the train being placed upon the bridge in a state of repose. This important fact was confirmed in all its entirety by the larger experiments made by the commissioners on the Ewell bridge, on the Epsom line, and the Godstone bridge, on the Southeastern line.

Colonel James found that when a carriage was loaded with 1,120 pounds and placed at rest upon a cast-iron bar, it produced a deflection of six-tenths of an inch; when, however, the carriage moved over the bar at the rate of 10 miles per hour, the deflection was increased to eight-tenths of an inch; when the speed of the carriage was increased to 30 miles per hour the deflection was increased to one inch and a half, which is more than double the statical deflection. It follows from this that a much less weight will break a bar of cast iron when it moves over it at a great speed than if it be placed at rest upon the bar. The bars, when broken by a load passing over them, were fractured at points beyond their centres, often into four or five pieces, indicating the unusual strains to which

they had been subject. From these unexpected results there is no appeal, however much they may be at variance with the impressions of the most gifted engineers. It now remains to connect these results with well-established mechanical laws, a problem of great difficulty, the solution of which has been accomplished by the labors of Professor Willis and Professor Stokes. (See "Preliminary Essay on the Effects produced by causing Weights to travel over Elastic Bars," by the Rev. Robert Willis, F. R. S., &c.)

By neglecting the inertia of the bar, as being small in relation to the moving weight, Professor Stokes has shown that—

$$D = S + \tfrac{1}{2}\left(\frac{VS}{l}\right)^2.$$

D=central dynamical deflection of the bar, produced by the weight moving at the velocity V.

S=central statical deflection produced by the same weight.

l=the length of the bar in feet.

Hence the dynamical deflection is double of the statical, when the velocity of the moving weight is $\sqrt{2}$ times the length of the bar between the supports.

These results were not readily accepted by practical men, as they had been accustomed to connect high velocities of the train with small deflections of the bridge over which it passed.

The late Robert Stephenson, in his evidence before the commissioners, states that he had seen the deflections less as the train passed over than when it was in repose. From the observations which he had made he felt quite satisfied upon the point, that no revision of the practical rules respecting the deflection of the bridges was necessary. "You will sometimes find," he adds, "an exceptional case occurs, if the engine happen to jump on the springs, which may, of course, accidentally occur; but if it be a mere question of velocity I do not think it increases the strain upon the girder. There may be a lateral strain backwards and forwards when the whole train comes into play and causes a jerk."

Mr. Locke, after making many experiments with locomotives passing over bridges, arrives at the conclusion that there is but little difference in the deflection between high velocities and low. "If there be," he remarks, "three or four bad rails or joints upon the top of a bridge there is far more effect produced upon the bridge. A bad joint is more serious than 10 or 12 miles' increase or diminution of velocity."

Mr. Hawkshaw's opinion is, that there would be a greater deflection in a bridge by running a weight over it than by allowing the same weight to rest upon it, because there is always an irregularity in the surface of the rails, and the force of impact is thereby brought into activity. W. H. Barlow stood under a wooden viaduct while a heavy goods train passed over it. There was a slight deflection produced by the heavy train, but the express, with a much lighter engine, and moving at a greater speed, produced a much worse effect. It seemed to produce a wave through the bridge, as it ought to do from the ordinary principles of dynamics. This load was passing over the bridge in a very few seconds, and therefore the total deflection is performed by the weight in a few seconds; and it therefore becomes a kind of blow—the descent of a heavy weight—and the bridge has not time to accommodate itself to the deflections required of it. These deflections are propagated throughout the structure, and may prove exceedingly dangerous and disagreeable.

Mr. Rastrick always considered that when a weight passed rapidly over a structure, there would be less deflection than if it were stationary. He takes the example, for comparison, of a man skating upon ice, and states that if he remain stationary for a length of time he would soon go through the ice; but he may skate over it without any danger of going through, because the ice has no time to break.

Mr. Brunel's impression was that where the rails are perfect the deflection is, as it ought to be, less with a weight passing rapidly over it than when it rests upon it; "but the experiment is so difficult to make, from the number of interfering causes, that perhaps my impression is still only prejudice rather than positive information."

Mr. Cubitt, engineer of the Great Northern railway, could perceive no difference in the deflection of a large girder between the weight being stationary upon it and passing over it at a great speed. The experiment was made upon a girder 47 feet span, and a heavy locomotive engine, the deflection being a tenth of an inch

The opinion of Mr. Charles Fox, engineer, is very decided on this point. He states positively that, if the rails have been carefully laid over the portion of the line resting upon the bridge, less deflection is caused in the girder by a load passing at a high speed than at a low one, and that there is less deflection with any rate of speed than when the weight is stationary. "I imagine this arises, in a great measure, from the short time there is to overcome the inertia of the mass; of course the higher the velocity the less time is expended in the train passing over the bridge."

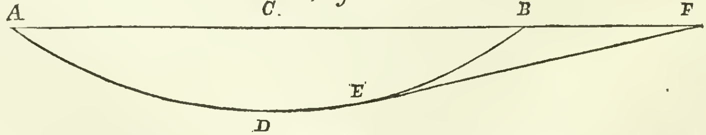
Mr. Glynn, of Butterly Iron Works, Derbyshire, thinks that, if the strength of the beam were not great in proportion to the stress it had to sustain, the weight, being stationary upon it, would tend to deflect it permanently more than a weight passing rapidly over it. "This opinion is not formed from experience; experiments on the subject would be very desirable."

This is the testimony, conflicting as it is, of the highest authorities in the engineering profession respecting a most important part of their practice, viz: the permanent stability of structures over which thousands of people are being continually conveyed with rapid velocities.

Perhaps the simplest method to gain the conviction that the dynamical deflection of a structure is different from its statical deflection is to place a weight, capable of motion, and producing a sensible deflection, on the middle of a horizontal flexible beam, between fixed supports. Let us now inquire what effect is produced by moving the weight to a point very near to its original position. It is evident that the weight, being at the lowest point of the beam, cannot move from this position without the application of a force. The effect of this force upon the moving weight and flexible beam will, of course, depend upon its magnitude and direction. If the direction of the force be vertical, whatever may be its magnitude, it will not produce any horizontal motion in the moving weight. If the direction of the force, however, is not vertical, the case is very different.

The movable weight, abandoned to the influence of gravity and the reaction of the beam, will have a complex, vertical, and horizontal motion, while the flexible beam will be, from the same cause, put into a state of periodical oscillations, the number and amplitude of which will depend upon the moving forces

Fig. 5.



and inertia of the beam. Let A B be the fixed supports of the beam, A D B its position after the weight has been placed upon it. If the point E in the beam is sufficiently near to D, then the line D E may be considered straight; produce D E to meet the horizontal line A B in F, and put the angle D F B$=\theta$. Let the force H, applied to move the weight from D to E upon the inclined plane D E, be in the direction of D E. It is evident that the force H can be decomposed into two, viz., H sin θ acting vertically upwards, and H cos θ acting horizontally

from D to E. If we examine the effect of these two decomposed forces it will be found that the force H cos θ, which is nearly equal to H, since the angle θ is small, will produce an elongation in the beam A D, and a compression in the beam D B. When the elongation of A D is greater than the compression of D B, the beam between the supports is increased in length; hence the middle point D, where the weight is placed, is moved vertically as well as horizontally into another position. From this force alone the beam would become a wreck if the force H, or the velocity with which the weight is moved from D to E, was sufficiently large; but, to prevent this catastrophe, the vertical component force H sin θ diminishes the reaction of the weight and beam. The vertical force of the weight, instead of being the weight alone, is now diminished by H sin θ, and is become W − H sin θ, where W is the weight of the movable body. The effect then of the vertical component is directly opposite to that of the horizontal component; and it is evident that under certain conditions either one or the other of these two forces may prevail. Hence the indications of theory are in harmony with the observations of engineers, and fully justify the conflicting evidence which they have given on the subject. Sometimes the conditions of the moving weight and the beam are such as to produce a statical deflection greater than the dynamical, and sometimes the conditions produce a dynamical deflection greater than the statical. The computation of the effects of these component forces is attended with great difficulty, as they bring into full activity the elastic forces of the beam and its inertia. The solution, however, of this intricate problem, under certain restrictions, viz., when the weight of the beam is small compared with the moving weight, and the deflection small compared with the length of the beam, has been given by Professor Stokes. (See "Transactions of the Cambridge Philosophical Society," vol. viii, p. 707.)

The same distinguished analyst has given another solution to this problem when the mass of the moving weight is neglected, or the effect of the weight reduced to a travelling pressure. The exact solution of the problem lies between these extreme cases, and is therefore circumscribed by the labors of Professor Stokes in such a manner that it can be approached to any degree of proximity required. The general dynamical equations from which the dynamical deflection is computed are so complex that a complete solution of the problem, as exhibited in practice by the moving weight being sustained by the beam in two points, is not likely soon to be furnished. Still, what has been accomplished by Professors Willis and Stokes is sufficient to show to practical engineers that the startling results of Sir Henry James and Captain Galton, as obtained at Portsmouth, and confirmed on the Ewell and Godstone bridges, are indicated by dynamical laws, the truth of which cannot be controverted. If this be true—and there can be little doubt of it—no engineer will be justified in neglecting a just estimate of its effects on the stability of structures on the safety of which human life depends. The commissioners appointed to inquire into the application of iron to railway structures have rendered essential service to the public by the discovery and experimental development of the difference between statical and dynamical deflection in iron girders. It is true they have not exhausted the subject, nor divested it wholly of its perplexity; but they have gained a positive and useful result, by showing to practical engineers the falsity of their position when they affirm that dynamical deflection is always less than the statical. I may state, in conclusion, that Professor Willis, by a train of reasoning which depends on the assumption of each particle of the beam moving into its position, forming the trajectory, at the same instant of time, has shown that the inertia of the beam is the same as it would be by placing half its weight at the centre.

This result is derived from a principle which is purely hypothetical, and the correct determination of which is the chief difficulty in the mathematical discussion of the problem. In the Appendix B to the commissioners' report, Professor

Willis has given the following dynamical equation, from which the trajectory of the curve described by the moving load may be computed:

$$\frac{d^2y}{dx^2}=\frac{g}{V^2}-\frac{ga^4}{V^2S}\frac{y}{(2ax-x^2)^2}:$$

y and x are the rectangular co-ordinates of the moving weight, the origin being at the extremity of the beam; y is vertical and x horizontal.

V=the velocity of the moving weight.
$2a$=the length of the beam.
.g=the force of gravity.
S=the central statical deflection.

This equation, and the reasoning by which it is established, accidentally fell into my hands during the time the commissioners were considering it, and in a letter to the secretary, Captain Galton, I pointed out the hypothetical principle on which the equation is founded. This principle is, that the reaction between the moving weight and the beam is equal to the weight which would be necessary to deflect the beam, when placed on it at rest, as much as the travelling load deflects it. This position is purely hypothetical, which may or may not give results approximating to the truth, according to the dimension of the quantities which constitute the fixed data of the problem. It is not improbable that this reaction, the amount and direction of which influence the motion of the moving weight over the beam, is continually vibrating between a maximum amount and zero, and that many times during the passage of the weight over the beam the reaction may be nothing, and therefore the moving load be abandoned to the influence of its own gravity only. However this may be, it is certain that its amount is never accurately measured by a formula which produces an accelerating force of

$$\frac{ga^4}{S}\frac{y}{(2ax-x^2)^2},$$

as given by Professor Willis.

This subject has received considerable attention from Mr. H. Cox, in a paper entitled "Dynamical Deflection and Strain of Girders," which is printed in the "Civil Engineer and Architects' Journal" for September, 1848. It appears that Mr. Cox has established, from the principle of *vis viva*, that the moving body cannot in any case produce a deflection greater than double the central deflection, the elasticity of the girders being supposed perfect. Professor Stokes, however, has shown that this conclusion of Mr. Cox is not true; that among the sources of laboring force which can be employed in deflecting the girders Mr. Cox has omitted to consider the *vis viva* arising from the horizontal motion of the body, and therefore has been led to an inference which is not correct. The recorded experimental facts connected with the dynamical deflection of bridges and bars of iron are given in the report of the commissioners as follows:

EWELL BRIDGE.

The span is 48 feet; the statical deflection produced by the engine and tender, 39 tons, and weight of half bridge 30 tons, was only .215 inch. This deflection was increased to .245, with a speed of 37 miles per hour. A speed of 51 miles per hour produced a deflection of .235.

$$\frac{\text{Greatest dynamical deflection}}{\text{Statical deflection}}=1.14.$$

GODSTONE BRIDGE.

The span is 30 feet, the weight of engine and tender 33 tons, and weight of half bridge 25 tons; the statical deflection was .19 inch. This was increased to .25 by a speed of 49 miles per hour.

$$\frac{\text{The dynamical deflection}}{\text{Statical deflection}}=1.315,$$

showing an increase of nearly one-third.

A pair of steel bars, two feet three inches by two inches broad and one-fourth inch deep, gave the following results:

Velocity in feet per second	......	15	14	29	34	44
Central deflection in inches	.70	1.02	1.32	1.45	1.30	1.03

A bar of wrought iron nine feet long, one inch broad, and three inches deep, with a load of 1,778 pounds, gave the following results:

Velocity in feet per second	......	15	29	36	43
Central deflection in inches	.29	.38	.50	.62	.46

In the commissioners' report Mr. Hodgkinson has given the results of a variety of experiments on the transverse strength of cast, mixture of cast and wrought, and wrought iron. The experiments were made with great care, and every source of error that could be was eliminated, notwithstanding the trouble and expense which such a procedure necessitated. Still there was a great difficulty, which was always felt by Mr. Hodgkinson, and which occupied, at various times, much of his attention, viz., to connect the breaking-weight of the beam with its deflection in such a manner as to indicate true practical results. For this purpose he entered into a very general theoretical investigation on the transverse flexure of beams, which is given in the second volume of Tredgold "On the Strength of Cast Iron;" but, in order to make the results of this very general investigation practical, he is compelled to assume, first, that the forces of extension and compression are proportional to the extensions and compressions; second, that the force of extension is equal to the force of compression; third, the reaction at the points of support is always vertical. It is not surprising, then, that a formula, based upon so many assumptions, should fail to represent correctly the relation between the breaking-weight and the dimensions of the beam; this is exactly what has taken place.

The discordance here alluded to has arrested the attention of W. H. Barlow, esq., C. E., F. R. S., and the results of his investigations are given in two very interesting memoirs, printed in the "Transactions of the Royal Society" for 1855–'57. It would be great presumption on my part to enter into any profound criticism on the mode of procedure and results of these memoirs, revised as they have been by Professor Barlow, who is justly distinguished by his genius, high attainments, and long life devoted to the interests of science; but still it may not be out of place here to make one or two observations which occurred to me while reading the memoirs. I quite agree with Mr. Barlow that there must be other forces in operation when a beam is broken transversely than those simply and usually designated tensile and compressive. If a beam is broken transversely, and the existence and position of the neutral surface are admitted, then it is not difficult to conceive the existence of a third force between two adjacent laminæ unequally extended or compressed.

This is really what happens, and the existence of which was well known to

Mr. Hodgkinson, who thought it to be so small in practical cases that its accumulated action would not produce much effect on the breaking strain of the beam.

Be this, however, as it may, there is some little difficulty in subscribing to all that Mr. Barlow advances on this important and interesting subject. In the first place there might be an exception taken to Mr. Barlow's method of fixing the position of the neutral line. Does he not fix it by an appeal to his senses rather than by the result of the mathematical analysis of the data he has obtained from experiment? The position which he fixes upon, viz., the centre of the beam, necessarily involves the equality of tensile and compressive forces, a conclusion which is not justified by Mr. Hodgkinson's experience. In the second place Mr. Barlow makes it appear that the error in the breaking strain of a beam is nearly one-half by neglecting the force of adhesion between the adjacent laminæ. We hardly think this conclusion is based upon sound premises, although it necessarily follows from the results of a formula which has been obtained by considering only the two forces, viz., tensile and compressive. But it is hardly fair on the part of Mr. Barlow to institute a comparison between the *resistance to flexure* and the results of a formula ($W = \frac{2}{3}adf \div l$) in which that *resistance to flexure* is neglected, without applying the well-known corrections to that formula. When a beam is strained to a considerable extent the deflection becomes sensible, and of course the reaction at the supports, being perpendicular to the surface of the beam, makes an angle with the vertical. This circumstance affects the above formula in two ways: first, it alters the amount of the moment about a line in the neutral surface; and, second, its tendency is to change the position of the neutral line. Therefore, unless these corrections are approximated to and applied to the formula, it is not safe to infer, as Mr. Barlow has done, that, by neglecting the *resistance to flexure*, the ordinary formula only gives nearly half the breaking weight.

Another source of error is in the law *"ut tensio sic vis,"* as it is well known, from Mr. Hodgkinson's experiments, that the forces of extension and compression are neither equal nor vary with the extension and compression when the strains are large. I quite agree, as did Mr. Hodgkinson, with Mr. Barlow as to the existence of a *resistance to flexure* in the transverse strain of beams besides the ordinary forces of tension and compression; but the mode of estimating this *resistance to flexure* in Mr. Barlow's second memoir amounts to the assumption that the force of extension varies by a law expressed by $ax+b$, where a and b are constants, and x the distance of the particle from the neutral axis. I may add, in conclusion, that Mr. Hodgkinson has computed the tensile and compressive forces, subject to a law much more general than the one here alluded to, with great clearness and adaptation to include practical cases.

Mr. Barlow's two memoirs, however, are the first on this subject to insist on the existence of a distinct force to resist flexure; and although I do not see the force of his comparison of the *resistance to flexure* with the results of the ordinary formula, or the theoretical method by which he estimates its amount, still I can with confidence recommend these memoirs to the engineering student as being worthy of his attentive perusal.

In concluding this memoir of one of the most distinguished members of the society, I cannot help feeling that the description herein given of his character and labors falls short of the real position which they occupy in the public mind; and although I have had much pleasure in reading and collating the discoveries of Mr. Hodgkinson, I regret that the preparation of this memoir has not been placed in abler hands. One thing, however, consoles me, and supplies me with an ample reward, which no criticisms on my effort can possibly cancel, and that is, I have been engaged, to the best of my ability, in the endeavor to perpetuate the memory of a great and good man, whose singular praise it is to have spent his life and his great powers for the good of mankind, with a single aim to truth and science, without desiring or gaining pecuniary reward.

RECENT PROGRESS IN RELATION TO THE THEORY OF HEAT.

By A. Cazin.

*Translated for the Smithsonian Institution.**

The study of heat presents a remarkable example of the connection which exists between the physical properties of matter. Restricted as the limits of this discourse must necessarily be, I propose on the present occasion to consider heat under two points of view only, first in its relations to light, and next in its relations to movement. It may thus be practicable to furnish a rapid sketch of the actual state of this part of physics.

The fact that the same laws are applicable to the propagation of heat and to that of light, is one which science leaves no longer in doubt. To every experiment in optics there corresponds a similar experiment in thermotics. The methods of observation are to-day carried to such perfection that M. Desains has been able quite recently to reproduce with heat the remarkable phenomenon of the luminous interference from striated surfaces.

A pencil of horizontal luminous rays traverses a plate of glass on which are traced parallel lines extremely close to one another, (6,000 lines in an extent of one inch.) This pencil is divided by the plate into many distinct pencils, which spread themselves in fan-shape in a horizontal plane, and we see, on the screen upon which these pencils are made to fall alternate intervals of light and obscurity. With the violet light the dark intervals are not so large as with the red. This is the phenomenon of diffraction discovered by Frauenhofer. By applying a thermo-electric battery, the most delicate of thermometers, at different places in the plane where the pencils transmitted by the luminous rays are distributed, M. Desains has verified the existence of pencils of heat distributed like those of light. Moreover, by causing obscure heat, proceeding from a solar pencil which has passed through M. Tyndall's solution of iodine in bisulphide of carbon, to fall on the rays, M. Desains has observed that the intervals without heat are greater than the obscure intervals given by the red light. Remark now the gradation: the violet is more refrangible than the red, the red more refrangible than the obscure heat, consequently the magnitude of the intervals destitute of rays varies in inverse proportion to the refrangibility.

Several other experiments in optics have been transferred by M. Desains to the domain of radiant heat. I will cite one of those relating to the polarization of obscure heat. The rays of heat employed issue from a common oil lamp; a lens of glass collects them and causes them to converge on a prism of Iceland spar achromatized. Two pencils issue from this spar: that which is called the ordinary pencil encounters a second prism of spar like the first; it is bifurcated in its turn. Of the two pencils thus obtained, that which is called *ordinary-ordinary* falls on a lens and converges towards the thermo-electric battery. When the principal sections of the two spars are perpendicular, neither light nor heat arrive at the battery; the *ordinary-ordinary* pencil is said to be extinguished. If one of the spars be now made to turn upon itself, light and heat immediately appear in this pencil. Let us now place between the two spars a trough, containing Tyndall's solution; the luminous rays are arrested, and beyond the trough there remains only the obscure heat. The destruction of this heat is complete when

* From the *Revue des cours scientifiques de la France et de l'étranger*, "Association Scientifique de France, (conférences de la Sorbonne,") 1867.

the principal sections of the two spars are perpendicular. Here, then, we have the experimental demonstration of the polarization of obscure heat.

Let us next place between the trough and the second spar a lamina of quartz, the thermo-electric battery manifests heat anew, just as if, without interposing the quartz, we had caused the first spar to turn by a certain angle. It is usual to say that the ordinary pencil which issues from the spar is polarized in the principal section, and that the transmission of this pencil through the quartz causes the plane of polarization to revolve. To conclude the experiment, we cause the first spar to turn until the *ordinary-ordinary* pencil which encounters the battery is extinguished anew, and the angle of this rotation measures the rotation of the plane of polarization.

The perfect resemblance of a luminous and a calorific ray has led to the inference that the forces which are at play in the two radiations place matter in a similar state of movement. Would we figure to ourselves a state of movement capable of producing all the phenomena of light, we have but to imagine an infinitude of particles situated upon the ray and oscillating from one side to the other of an intermediate position, like the particles of a chord which yields a sound; two consecutive particles act one on the other in such a way that every modification of movement in the one induces a determinate modification in the other. While a particle executes a complete oscillation the movement is transmitted to a certain distance which is called *length of wave.* Here we have the point of departure of the theory of undulations; the same hypothesis is applicable to heat.

From the fact that the propagation of heat and light takes place as well in a vacuum as through ponderable bodies, the above hypothesis must be thought incomplete unless it be supposed in addition that the matter which transmits the undulations is different from ponderable matter; to the former, therefore, has been given the name of *ether.* Were this vibrating matter even of the same nature with the matter of ponderable bodies, it would still be useful to employ a special word to indicate that it is in a particular state, capable of propagating light; as the purpose in using it is to represent to ourselves the possible mechanism of the phenomena, we should, above all, seek simplicity of language, and the use of the phrase *luminous ether* satisfies this condition.

It may naturally be asked whether there is a *calorific ether* distinct from the *luminous ether*, or whether one sole ether is sufficient for the mechanical representation of the radiation of light and of that of heat. Only one, it is evident, should be admitted, if that suffices for the explanation of all the known facts, and the question here relates to facts which take place in the material world, outside of ourselves and independently of our sensations. To the well-known researches of MM. Jamin, Masson, and Delaprovostaye, which corroborate the hypothesis of a single ether, we should now add the late investigations of M. Desains on the rotation of the plane of polarization of the rays of obscure heat in passing through quartz.

When the question relates to luminous rays we know that the rotations of the plane of polarization are inversely proportional to the squares of the lengths of wave. If there be luminous rays having a length of wave four times greater than that of the violet rays, their rotation, according to this law, would be 16 times smaller than the rotation of these last. Now, MM. Delaprovostaye and Desains had heretofore established that calorific rays and luminous rays of the same length have the same rotation. And now M. Desains shows us that the rays of obscure heat satisfy the law as enunciated, and among these rays there are such as have, in fact, a rotation 16 times less than that of the violet, and a length of wave four times greater.

Instead of assuming that two like systems of waves propagate, the one heat, the other light, while they undergo the same modifications by reflection and refraction, is it not more simple to admit but a single system, the longest waves producing the effects of heat, and the shortest those of light? Such is the import

of the principle of the identity of heat and light; it explains all observed peculiarities of radiation, whether chemical, calorific, or luminous.

If we would comprehend, for example, how a solution of sulphate of quinine is luminous in a dark chamber, when it is placed in the ultra-violet region of the solar spectrum? Imagine a series of tuning forks of different magnitudes assembled together in the same place, and a sound produced at a distance. Several of the forks will be thrown into vibration, namely, those which are capable of rendering the harmonic sounds of the exciting sound. Sonorous waves, longer than the incident wave, will proceed from the forks which render grave harmonic sounds: the exciting sound will have generated graver sounds. Such is the analogy of *fluorescence*. The radiations incident to waves too short to excite the retina generate in the sulphate of quinine longer waves, which are capable of producing the sensation of light. Inversely an obscure radiation of a wave too long to be luminous may, by encountering certain bodies, occasion therein more rapid ethereal vibrations, and generate shorter waves, which shall be luminous. These vibrations are analogous to those which correspond to the sharp harmonics in the acoustical experiment which I have adopted for exemplification. Here we have the image of that kind of calorific and luminous phenomenon which M. Tyndall has termed *calorescence*.

The ray of heat which penetrates into a body is absorbed therein either in whole or in part. So long as the question concerns a solid or liquid body we feel no doubt as to the exactness of this proposition; it is the simplest expression of observed facts. But when it relates to a gas or to vapor the absorption is much more difficult to demonstrate. We owe to M. Tyndall, in England, and to M. Magnus, in Germany, the experimental proof of the absorption of heat by gases and the measure of that absorption.

The experiments of M. Pouillet on the solar heat long since taught us that the atmosphere retained a considerable portion of the rays emanating from the sun; but which of the gaseous elements of the air exerts the greatest absorption? At present some approximation has been made to the solution of this important question, and I shall attempt to show at what point it has arrived.

To ascertain the absorption of heat by a gas, we will take, like M. Tyndall, a tube of plate-tin of the length of two metres, which bears a tubulure in the middle and a tubulure towards each end. A pencil of obscure heat traverses this tube, and encounters the thermo-electric battery. The calorific effect indicated by the galvanometer is due, in part, to the rays which pass into the tube parallel to its axis, in part to those which have undergone sundry reflections on the walls of the tube; the tube contains at this time only common air, naturally humid. We exhaust this air by the tubulure of the middle, by means of a pneumatic machine; as the tube is open at both ends the atmospheric air enters freely, and notwithstanding the removal of the strata of air, the needle of the galvanometer remains at rest. If coal gas be now introduced through the terminal tubulures the deviation of the needle diminishes, which shows that heat no longer traverses the tube as freely as before. Arrest the introduction of the gas by continuing the action of the pistons of the pneumatic machine, air replaces the gas, and the needle returns to its former deviation. From this experiment it is inferred that coal-gas has an absorbing power superior to that of atmospheric air.

M. Tyndall varied this experiment by causing dry air to pass into the tube, and observed an augmentation in the deviation of the needle of the galvanometer. From this he concludes that the absorbing power of humid air is greater than that of dry air, and that aqueous vapor exerts on heat a considerable degree of absorption. A great number of experiments made by other methods has led him to the same conclusion. On the other hand M. Magnus, in operating after M. Tyndall's or by other methods, found that humid air acted very nearly as dry air, and that any great difference was only manifested when water exists in the air in a vesicular state, similar to the water of clouds.

The experiment of M. Tyndall, of which I have attempted to give an idea, seemed to be of a nature to decide the question in favor of the English physicist. But it is in reality a very complex question, as is shown by the latest observations of M. Wild, of Berne, and those of M. Magnus. The state of the wall of the tube exerts a highly important influence on the effects obtained. It is true that humid air communicates less heat to the battery than dry, if a tube polished on the inner side be employed. But if the tube be blackened or lined with velvet an inverse effect is observed; humid air then conveys more heat to the battery than dry. The complication of the phenomenon is connected with the condensation of the vapor of water on the walls of the tube. It appears, therefore, extremely difficult to measure the absorbing power of aqueous vapor by the methods which have heretofore been practiced; all that can be concluded from numerous observations up to the present time is that this power is not so considerable as M. Tyndall thinks. If we consider, however, the terrestrial atmosphere in relation to the vesicular water it contains, absorption will appear due principally to that water, and the climatological conclusion of M. Tyndall be free from objection.

In what light should we regard the mechanism of absorption? If we admit in bodies the existence of ponderable particles and an ether, we can suppose that the movement of the ether is transformed into a different movement, effected by the particles of the body when absorption occurs. We are led to believe that this transformation is more facile in compound bodies that in simple, from seeing that the absorbent power of the former is in general greater, and we can imagine compound bodies to be aggregations of particles whose form is opposed to the vibrations of the ether. M. Tyndall says that simple gases are to compound gases what a smooth cylinder, revolving in water, is to a wheel with paddles. The verification of such a law is of very great importance, and we thus see how the research respecting the absorbent powers of gases and vapors may disclose remarkable correlations between the different properties of matter.

In the same way that we just represented to ourselves the absorption of heat by gases, we can also represent its emission; it will be the transmission of the movement of the particles of gas to the ether, and two gases will present the same relation between their absorbent and their emissive powers. The emission of heat by gases is well established by the experiments of MM. Tyndall and Magnus; there remains no uncertainty but with regard to the numbers which measure it. On this head new researches are indispensable.

There exist other phenomena calculated to reveal to us the relations of heat and light. It has been long known that the refractive properties of bodies vary with the temperature, and the study of this variation must greatly contribute to our knowledge of the constitution of bodies. M. Fizeau has been occupied with this study for many years, and he has been led to the origination of a new experimental method, the principle of which I proceed to explain.

The heat absorbed by a body is employed to produce many effects, among which is the change of its volume. When the question relates to a body sufficiently voluminous, the methods practiced leave nothing to desire. It is not so, however, in regard to bodies which can be obtained only in small fragments, such as crystals. The process of M. Fizeau is essentially as follows: The solid fragment, having the form of a lamina with two parallel faces, is placed on a horizontal metallic plane, supported by three long adjusting screws. The upper points of these screws support a plane of glass, beneath which is the solid lamina designed to be studied. By working these screws the lower face of the plane of glass is brought parallel to the upper face of the solid, at a distance of about two hundredths of a millimetre. By causing rays of simple light to fall perpendicularly on the lamina, rings, alternately brilliant and obscure, will be seen reflected on the latter. If the thickness of the small stratum of air interposed between the glass and the solid be gradually increased, the rings approach the

centre by a centripetal movement; the central dark ring becomes a black point and disappears; the second dark ring has taken its place, disappears in its turn, and so on in succession. Inversely, if the thickness of the stratum of air is diminished, the movement of the rings is centrifugal; a point appears at the centre, grows larger, becomes a ring; then a new ring is formed at the centre, and so in succession. When a ring proceeds thus to occupy the place of another ring, we know, according to the laws of light, that the thickness of the stratum of air has varied by a half length of the wave; for yellow light this variation is 294 millionths of a millimetre. Observation of the rings, therefore, will enable us to know the slightest variations in the thickness of the stratum of air.

The apparatus is placed in an air-bath, and is gradually heated. If the solid lamina dilates it tends to diminish the thickness of the stratum of air; the three screws, on the contrary, by dilating, tend to increase that thickness. The resulting effect will be a diminution or augmentation of the thickness, and consequently the centrifugal or centripetal movement of the rings will be observed, according as the dilatation of the lamina shall be greater or less than that of the screws. From the degree of displacement of the rings we deduce the dilatation of the lamina.

This method, the precision of which is extremely great if we take all the precautions indicated by M. Fizeau, enables us to resolve a great number of questions relating to the properties of crystals, and to establish new relations between heat and light. Thus there exist in a crystal three rectangular directions, which are called axes of elasticity, around which are grouped the most remarkable optical phenomena, and also the phenomena of conductibility and electricity discovered by De Sénarmont. These axes play the same part in the phenomena of dilatation by heat, and the ingenious researches of M. Fizeau have now completed our knowledge of the admirable structure of crystallized solids. Among the numerous unexpected results at which he has arrived, I may cite the contraction of the ioduret of crystallized or amorphous silver at every temperature which has been employed, and the existence of a maximum of density for the beryl, the protoxide of copper, and the diamond.

I pass now to the second part of my subject, the relations which exist between heat and movement. During the heating or the cooling of a body, there are in general three sorts of effects to be considered, the variation of temperature, the external mechanical labor which results from the change of the volume of bodies and from pressures exerted on their surface, and the internal mechanical labor which consists in the change of aggregation. There are definite relations between these effects and the quantities of heat lost or gained by the body, and the discovery of these relations is one of the most remarkable advances of modern physics. It serves as the basis for the mechanical theory of heat.

It is now well established by experiment that a given quantity of heat is equivalent to a definite mechanical labor, as if heat were convertible into labor, and *vice versa*. This experimental law leads us to regard the effects of heat as the result of the movement of the particles of bodies, and to frame hypotheses which enable us to conceive of this movement; but such is not the object of the mechanical theory of heat. Without forming any hypothesis respecting the nature of heat, it only sets forth a small number of principles, a sort of postulata suggested by experiments, and it links together all the known facts by means of general relations deduced mathematically from those principles. It is a physical theory in the rigorous acceptation of the word.

Till now two fundamental principles have served as a point of departure; but according to the recent researches of M. Hirn, the second principle would be a rational consequence of the first, so that *thermodynamics* would seem based in reality on the sole principle of the *equivalency of heat and of labor*. So important is such a proposition that I could not pass it by in silence.

The thermodynamic theory has opened a new horizon to all those who study

the physical and natural sciences. Admirable as has been its previous career, it has before it the most brilliant future. When our illustrious Ampère had divined the connection which exists between magnetism and electricity, electrodynamics was founded, and brilliant discoveries arose on every side. Our own generation has no cause to envy its predecessor; to the former pertains the credit of the development and application of thermodynamics. The formulas deduced from this branch of science have undergone the test of experimental scrutiny, applied by M. Regnault and other physicists; those formulas have other tests to undergo, by suggesting new experiments which had probably never been attempted without them.

The scientific association of France will contribute to this progress by facilitating and stimulating research. In this spirit its committee of physics has charged me with the study of the properties presented by saturated vapors when they undergo expansion or compression, and the results obtained have been published. The creation of new apparatus has led to other researches. It is thus that M. Hirn and myself have recently solved an important problem, respecting which there had not, to our knowledge, been any previous experimental information. I may be permitted here to give a statement of that problem: "A vapor supersaturated with heat is suddenly expanded by producing an external labor, without addition or subtraction of heat; what is the relation of the pressure to the temperature during the expansion?" There is an agreement between the results we have reached and the principles of thermodynamics; they prove that the changes of volume in vapors are accompanied by a considerable internal labor.

The laws which govern the internal labor of bodies are of the highest importance towards a knowledge of the constitution of matter, and yet those laws have been scarcely so much as surmised. To this day, experiments have had for their principal object the relations of heat and of external labor; it is from these experiments that have been deduced the numerical data now in use. The experiments relative to internal labor are more difficult and more rare. We have had recently the researches of M. Edlung, in Germany, on the thermic effects of the traction of metals. The principal experiment, and which the author has submitted to careful study, is the following: Along a stout piece of vertical wood is arranged a bar of metal terminated below by a ring, and firmly fixed by its upper extremity. Through the ring a strong iron lever is passed, one extremity of which rests on an axis attached to the piece of wood at a short distance from the ring, and the other extremity bears a basin at nine times that distance from the ring. When we place on this basin a weight of 60 kilograms, we exert on the bar of metal a traction of about 600 kilograms, the lever being of the second order. A thermo-electric battery has one of its faces applied against the bar, and a galvanometer shows the depression of the temperature. Let us now gradually lift the weight in order to allow the bar to return to its primitive length; the galvanometer indicates a corresponding elevation of temperature. Finally, if we suddenly remove the weight, there is again an elevation of temperature; but this time greater than before.

How is this phenomenon to be explained? Let us consider the bar as elongated by the external traction; its particles have taken such positions that the internal forces form an equilibrium to the external forces. If we suppress the latter, the body resumes its original volume through the effect of the internal forces, and there is an internal labor *expended;* there is a *manifestation*, therefore, within the body itself of a quantity of heat proportional to that labor, and, consequently, a spontaneous elevation of temperature; it is here taken for granted that the calorific action of neighboring bodies may be overlooked.

In place of suddenly suppressing the traction, let us allow the molecular forces to restore the body, little by little, to its original volume, by gradually diminishing the force of traction. The external labor thus *produced* will correspond

to an equal part of the internal labor *expended*, and the other part will be equivalent to the heat made apparent, consequently, to the elevation of temperature. This elevation will be less, therefore, than that of the preceding operation, and the difference will be proportional to the external labor produced.

But this operation may be reversed, and when we proceed in such manner as to dilate the body mechanically, there is an internal labor produced which remains greater than the external labor expended; the difference of these two labors corresponds to the disappearance of a proportional quantity of heat, hence a spontaneous lowering of the temperature,

Thus experiments of this kind furnish us a relation between the external labor, the internal labor, and the heat created or destroyed. On the other hand the mechanical theory establishes a mathematical relation between these quantities. It is practicable, therefore, to submit a consequence of this theory to the test of experiment. Such is the object which M. Edlung proposed to himself, and it may be said that the verification has been as complete as possible. But it does not appear possible to draw from such experiments the exact value of the mechanical equivalent of heat, on account of the impossibility of preventing the calorific influence of neighboring bodies. As the traction is not instantaneous, neither can the thermometric effect be so; the effect which we observe is therefore too small, and the theoretic formula which serves to calculate the mechanical equivalent yields a value too great. If we establish a system of corrections in regard to the effect of the surrounding bodies, the uncertainty is not less great, because of the minuteness of the thermometric effect that is measured.

By the side of the speculative researches which have aggrandized our knowledge respecting heat within a few years past, of which I have been able to signalize but a small number, may be ranged certain interesting experiments which have been devised for the popularization of science, and with which most of us are already familiar. I have selected one of those which we owe to the celebrated English professor, M. Tyndall, because it is the reproduction of a striking natural phenomenon. I refer to the intermittent eruptions of water and vapor met with in Iceland. M. Bunsen has furnished a very simple explanation of volcanoes of this kind, which are called geysers, and M. Tyndall has very ingeniously imitated them.

Imagine a pit of a depth of twenty metres, and a breadth of three; at the bottom there is water heated by the volcanic substances which proceed from the depth of the earth. The different strata of water occur under pressures increasing from above downwards, since each stratum must sustain the pressure of the atmosphere and that of the column of water which is above it. The temperature of ebullition of these strata will therefore increase, in like manner, from above downwards. Let us consider a stratum having a temperature a little below that of its ebullition, under the conditions in which it actually exists: if its pressure be diminished, it is thrown into ebullition. This is precisely what takes place in the geyser. Aqueous vapor being formed at the bottom of the pit, where the heat is strongest, lifts up the strata of water above. If one of them be raised sufficiently high, it passes into a state of ebullition; the water which is below it is less compressed; it boils in its turn, and a mass of vapor is instantly formed at the bottom of the pit. This vapor expels the upper strata of water, and itself issues with them, forming an immense sheaf-like jet. The expelled vapor io cooled, becomes liquid, and falls back with the projected mass of water; by its re-entry the temperature of the pit is reduced, and ebullition is suddenly arrested. We now hear a concussion proceeding from the formation of new bubbles fs water, because all the parts of the pit are not instantaneously chilled; until finally, repose is re-established. But the central heat gradually restores the column to its former state, and a new eruption takes place. In the experimental demonstration, the geyser is represented by a tube of metal, two metres in length, surmounted by a basin. It is filled with water, and tw › sources of heat are estab-

lished—one at the bottom, the other 60 centimetres higher up. By regulating the heat, the water of the latter region is maintained at a temperature a little below 103 degrees, and therefore cannot boil; but if the strata of the bottom are raised to 105 degrees, they are thrown into ebullition, and the steam raises the middle stratum. This is immediately reduced to vapor, and the eruption takes place. The mixture of water and steam falls back into the basin, re-enters the tube, and a certain interval elapses before the fires can re-establish the temperatures requisite for a new eruption.

In thus presenting to my auditors a view of some of the recent researches of physicists, I have endeavored to indicate the philosophic tendency of those researches. They lead us to presage new advances which will draw closer the bonds which science has discovered between the various forces of nature. Is it enough for us to picture to ourselves the mechanism of phenomena by the help of ingenious hypotheses? Hypotheses are useful to the physicist for the discovery of the numerical laws, which reveal to us the harmony of the universe; they do not suffice for the philosopher who wishes to ascend higher in the search for causes. But to the data of experimental science it is necessary to join principles of a wholly other order, the germ of which has been implanted in our souls by the Creator. The origin and essence of natural forces are questions of philosophy whose solution, if it is possible, exacts all the powers of investigation of which the human mind is capable.

THE PRINCIPAL SOURCES OF HEAT.*

In selecting as the subject of this discourse *the principal sources of heat*, I have proposed to give a very simple example of the connection which exists between natural phenomena, even those to which we might, if we contented ourselves with a superficial examination, deny a community of origin. But when mental practice has habituated us to observe what surrounds us, and to draw general conclusions from our observations, when we have learned to read, in some sort, the great book of nature, we hesitate no longer to recognize the connections which escaped us at first, and we seek an expression for those connections; when we have found that expression, we have constructed a physical theory. The theory which will serve me to show the connection of the sources of heat is very recent; it is alluring from its very simplicity. But being a work purely human, it is but a rough portraiture, a pale reflection of the grand unity which reigns throughout nature. All the merit of this theory consists in its being better than those which preceded it, and in seeming to approach nearer to the truth. This must justify us in adopting it.

Let us understand, then, the limits to which we are restricted; as far as concerns us at present, to explain a phenomenon is to show the connection which exists between that phenomenon and a general principle which is the expression of a fact more simple than experiment has revealed to us. I shall commence by establishing the fundamental principle on which I propose to sustain myself.

When a ball of ivory falls on a horizontal plane of marble, it rebounds and returns almost to its point of departure. Repeat the experiment, by replacing the ivory with lead, and the ball will rise to a less height in rebounding; but now it will grow warm, which was not the case with the ball of ivory. Cause soft bodies or liquids to fall; these will no longer rebound, and if we measure their temperature we shall find the heat created by the impact to be greater than in the previous instance.

It is now known that every pound of every ponderous body, which loses its velocity by falling from a height of about 720 feet, and which does not rebound, disengages a quantity of heat capable of raising by one degree the temperature

* *Conférence de M. Cazin.* "Soirée scientifique de Chartres." *Revue des cours scientifiques de la France, &c.*, July, 1867.

of a pound of water. This datum of experiment serves as a basis for all calculations relating to the *mechanical theory of heat.*

Here, then, there is a source of heat whose importance cannot escape our attention. Consider the innumerable falls of water which exist upon the earth, the waves of the ocean which resemble immense cataracts, incessantly renewed, and if we would represent to ourselves the enormous quantity of heat they produce, take as an example the falls of the Rhine at Schaffhausen. It has been calculated that this single water-fall creates in a day the heat required to melt 12,000 tons of ice.

Nor is heat created by the impact of heavy bodies alone. When any force has put a body in movement, it often happens that this movement is afterwards annihilated, that is to say, it stops without being communicated to other bodies, and heat becomes apparent. This is seen in the well-known experiment of the fire syringe. We exert a muscular effort on a piston; this compresses the air, and our force seems fruitlessly expended. But if it is not employed in communicating motion, it serves to produce heat; the compressed air is heated sufficiently to kindle gun-cotton. We will lay it down then as a principle that heat may arise from the destruction of movement.

Our habitual sources of heat are chemical combinations. I take sulphuric acid, diluted with water, in which I have immersed a small balloon containing ether; I put zinc in this acid; a lively chemical action is produced, and the mixture is sufficiently heated to throw the ether into ebullition. The jet of vapor rushes out by a slender tube, and may be made more conspicuous by kindling it. The solution of zinc in an acid is therefore accompanied by a disengagement of heat.

The heat disengaged in a chemical reaction is often sufficiently intense to produce incandescence, and when the vivacity of action is very great, an explosion. I shall cite some examples recently discovered, without going however into detail. A leaf of paper is moistened with pyroligneous acid; we touch it with a glass rod coated with a mixture of sulphuric acid and hypermanganate of potassium, and the paper immediately takes fire. Again, we let fall some drops of the essence of anise on the same mixture placed in the bottom of a glass; there is now both incandescence and explosion.

To manifest to my auditors the connection which exists between the heat created by impact and that created by chemical action, I take an example, well known, but on account of its simplicity, serving better than the preceding for the purpose of explanation. The powdered iron, suitably prepared, takes fire when exposed to the air. What is it that occurs in this phenomenon? One of the elements of the air, oxygen, combines with the iron and forms a brown powder, which is called oxide of iron. If the iron be weighed before and after the combination, it will be found to have increased in weight; this proves the fixation of the oxygen in the iron. Now, we shall very well represent to ourselves the mechanism of the combination, by imagining that the particles of oxygen have been precipitated on the iron and become fixed, just as the stone which falls on the earth remains fixed to the soil. Heat, then, has been created by the impact, and the connection we sought is established.

The chemical sources of heat are so important in the arts, that I shall more particularly dwell upon them, with a view to point out the recent improvements of which they have been the object. It was only the combustion of charcoal, accelerated by the insufflation of a considerable quantity of air, which for a long time was made use of in industry; such is the fire of the smelting furnace, which can melt iron, but is incapable of melting platina. This metal, as precious as gold, could be melted by no known chemical process until quite recently, when the means were devised by M. H. Sainte-Claire Deville. At present we melt it very easily by the combustion of illuminating gas with pure oxygen. In this process the oxygen contained in a gasometer issues by a copper pipe terminated by

a tip of platina. This pipe is in the axis of a second and larger pipe of copper, whose extremity is also of platina. The illuminating gas issues forth, filling the interval comprised between the two pipes. We have thus a jet formed by a mixture. We kindle this jet and introduce it into a furnace composed of lime; the flame whirls with resonance in the midst of the furnace, heats it intensely, and issues by a lateral opening. It is by this opening that we introduce the platina under the form of thin laminæ. Each lamina disappears as if swallowed up, and a sparkling liquid trickles to the bottom of the furnace.

We stop the jet of flame and uncover the furnace; the liquid platina is so dazzling that we may extinguish the gas burners in the hall, and we are illuminated as by the electric light. We pour the liquid in a vase of limestone, and can see its perfect fluidity. By degrees it grows cool in the air, and finally becomes a solid; but it is so heated that it will remain a long time luminous.

When there is need but of a moderate heat, the combustion of illuminating gas by the ordinary air is often preferable to that of coal, and the construction of apparatus for warming by gas is at present carried to great perfection. The principal improvement is due to the distinguished German chemist Bunsen, who has devised an excellent arrangement for completely burning the gas.

The Bunsen burner is essentially formed of two concentric pipes; the gas is conducted into the inner one; the external pipe being open at the two extremities, the atmospheric air naturally enters, mingles with the gas, and it is this mixture which is kindled. The flame is but slightly luminous, but very hot; if we prevent the access of air, the flame becomes brilliant, because the carbon of the gas is not immediately burned by the oxygen of the air, and it remains for some time as a solid dust raised to a very high temperature. It is the presence of the free carbon which enables the flame to be illuminative; the form of the burner for giving light is such that the carbon is not burned so soon as the hydrogen of the gas, while in the burner of Bunsen it is burned at the same time. A single one of these burners, of a suitable size, is sufficient to melt silver.

At present the Bunsen burners are of the greatest service in our laboratories; they are employed for heating the tubes for chemical analysis, and quite recently an arrangement has been contrived which secures for this mode of heating the greatest regularity. The mixture of air and gas issues by some sixty small holes pierced in a cylinder of fire-proof earth, and all these small flames raise the cylinder to a red heat, in such sort that the caloric is uniformly diffused in all directions. Some hundred jets of this sort, suitably disposed around a glass tube, raise all its points to the same temperature without risk of fracture or distortion of the tube. Is it possible to attain a temperature sufficient for the fusion of platina by burning simply a mixture of air and coal-gas? It is the presence of nitrogen, an element of the air altogether inert, which hinders the temperature of combustion of such a mixture from being as high as that of the mixture of gas and pure oxygen. The nitrogen appropriates a part of the heat created by the chemical combination, and moreover it embarrasses the contact of the oxygen and the combustible. The employment of air would nevertheless be much preferable to that of pure oxygen, when an industrial interest is in question, on account of the dearness of the latter and the difficulty of its preparation. Hence it has been sought to solve this problem; and, by applying to the blow-pipe of M. Schlæsing the principle of the ventilator of M. Demontdésir, M. Wiesnegg has succeeded in melting platina by means of a mixture of air and coal gas.

In the blow-pipe of M. Wiesnegg, as in that of M. Schlæsing, compressed air arrives by a small orifice at the bottom of a tube, and the gas penetrates into this tube by a lateral tubulure in advance of the jet of air. The mixture is kindled at the outlet from the tube. But in the blow-pipe of M. Wiesnegg, the air being very strongly compressed, issues with great velocity; it briskly draws in the gas, and holes being pierced around the orifice of efflux, the atmospheric

air is itself drawn in, and penetrates into the blow-pipe, which considerably augments the total quantity of air mingled with the gas. In order to evince this fact of the aspiration of the surrounding air, we kindle the jet and direct it into a small furnace of brick, analogous to the furnace of lime, which has served us for melting platina. The flame issues with resonance by a small aperture, and the walls of the furnace are rapidly raised to a red heat. We now let fall powder of iron around the holes of the blow-pipe; this powder becomes heated in the furnace and issues with the flame in brilliant sparks. The necessary accessory of the blow-pipe consists in a powerful bellows, which impels the jet of air under a pressure of two atmospheres. For this purpose a pump compresses the atmosphere in a reservoir, while a tube of resistant caoutchouc conveys the compressed air from this reservoir into the blow-pipe.

In this way the inconveniences of the nitrogen contained in the air are lessened. In the blow-pipe of M. Wiesnegg, the air is so intimately mingled with the gas that the inertia of the nitrogen offers the least possible opposition to the rapidity of the chemical combination. Now, it is on this rapidity that depends the temperature of the flame. The more rapid the molecular movements which create heat, the higher the point to which the temperature is raised; because the environing bodies have not time within a certain limit to absorb that heat.

I limit myself to these applications of the chemical sources of heat, and pass to a source of quite another kind — to that which has furnished us the highest known temperatures, and which can reduce to vapor the diamond itself. None of the preceding methods enable us to modify this substance; it is the most refractory of which we have any knowledge.

Conceive a sheet of zinc and one of copper plunged into sulphuric acid, diluted with water. We know that the zinc combines with the elements of the liquid, producing heat. If we unite the two sheets by a metallic wire, the latter becomes heated, which indicates that it is the seat of a peculiar modification. The cause of this modification we name electricity, and we say that the assemblage formed of the acid, the metals and the wire, is traversed by the *electric current.* Now, if we measure the heat produced in the acid and in the wire, we find it to be, for a certain weight of zinc dissolved, the same as if the metal were simply dissolved in the acid without the wire, which gives passage to the current. The sole difference which exists between these two modes of operating consists in the heat being differently distributed; in the act of the dissolution of the zinc in the acid without an electric current, the heat is only produced at the place of the chemical action; when there is a current, this heat is produced simultaneously in all the parts of the circuit traversed by the current. In order to exhibit the heat disengaged in the electric circuit, a battery has been arranged outside of the apartment occupied by my audience; that battery being an assemblage of sheets of zinc and acidulated water in which the chemical combination is effected, while the metallic wire which serves to close the circuit extends to myself for the performance of the experiments. At this moment the wire is divided, and I hold in my hand its two extremities; I touch with them the two ends of a fine wire of platina, 50 centimetres in length, so that the circuit is now closed. The current passes, and we see that the wire of platina is heated to a white red; it in fact melts, and no doubt therefore can remain of the disengagement of heat which I announced. The two wires with which I touched the platina were of copper, and their diameter was about two millimetres; these also have become heated, but the elevation of their temperature was slight, simply because of their thickness.

I shall not seek on this occasion to explain how electricity effects the distribution of heat in the circuit of the battery; I propose merely to mention this means of producing heat, the discovery of which we owe to Volta, and which dates but a half century ago. It has been seen that this source of heat is of chemical

origin, and consequently the connection which it has with the sources previously spoken of is sufficiently established.

It remains for me to show how the Voltaic circuit realizes the highest temperature known. We attach to the extremities of our two copper wires cylindrical pieces of charcoal; we then bring these cylinders into contact with one another. The circuit is now closed. If we separate these two pieces of charcoal, a mass of dazzling light fills the interval between them and re-establishes the continuity of the circuit. What is this light, which has received the name of the *Voltaic arch?* It is a volume of incandescent particles of charcoal, which acts in like manner with the platina wire of the preceding experiment. This mass of particles is vehemently heated by the passage of the current. In order that its enormous temperature may be appreciated, we project it on a tablet by means of lenses, having first enclosed it in a suitable box, that the eyes of the spectators may be sheltered from its blinding brightness. By this expedient, we are enabled to view all the details of the Voltaic arch. On the tablet we may see the reversed image of the sticks of charcoal, themselves heated to white-red, as well as that of the arch, which appears as a violet flame. Let us place a sheet of platina in this flame; it melts rapidly, and the fused platina collects in a sparkling globule on one of the pieces of charcoal. Thus, the heat is at least as strong as in the furnace which, an instant ago, we heated by a chemical process. But it is much stronger, and if we placed a diamond instead of platina in the Voltaic arch, it would be seen to become soft and begin to melt. Were we to conduct this operation in a vacuum, the vapor of the diamond and that of the charcoal of the apparatus would be deposited on the walls of the vase. This experiment was made for the first time by Despretz, at the Sorbonne, with a battery of adequate power.

The sources of heat which I have thus far noticed are at the disposal of man, who can regulate them at his pleasure; these are *artificial sources*. It remains to speak of the *natural sources*—of those whose power the Creator has regulated, in order to constitute the universal harmony of nature.

It is impossible to explain in this short discourse, by what admirable laws heat is incessantly generated by animals. It suffices to recall the fact that this heat has a chemical origin, in order to comprehend that it is referable to the same fundamental principle with the others. In effect, the carbon and hydrogen furnished by our aliments are placed in presence of the atmospheric oxygen by the act of respiration, and their chemical combination is effected in the blood, attended with the customary disengagement of heat. I should add, however, that animals further create heat by another process purely mechanical. When a man, for instance, goes down stairs, his body is displaced and falls, as it were, from a small height; he displaces it anew, again falls, and continues doing so. Now, each of these little descents creates heat, like the fall of every heavy body which does not rebound. One of our most distinguished savants, M. Hirn de Colmar, has succeeded in measuring the heat thus produced, and finds that it very competently satisfies the general law.

I might also speak of the heat disengaged by vegetables, at certain epochs, when their organs are the theatre of intense chemical reactions; at the same time, I should say that it is much rather their rôle to consume heat than to produce it, and that in this the functions of vegetable life are made to compensate those of animal life. But I am about to transport my audience into other regions, in essaying to lift a corner of the veil which renders them so mysterious.

The grand and most wonderful source of heat is the sun. The genius of man, bursting at a bound its terrestrial shackles, has long since overleaped the distance which separates us from that marvellous luminary. It has measured, it has weighed it, and we are to-day very remote from the time when men bowed in awe before it as before a divinity. Taking as a guide the observations conducted by

M. Pouillet, we find that the sun disengages in a year a quantity of heat capable of melting a covering of ice 1,500 leagues in thickness, which might envelop a globe one million four hundred thousand times larger than the earth.

How are we to explain this enormous production of heat? Is it the result of a combustion analogous to those which take place on our hearths? To be convinced of the impossibility of such an origin, it suffices to know that if the sun were a globe of charcoal burning in oxygen, it would be consumed in 5,000 years.

The new theory of heat has led to an hypothesis which satisfies the mind up to a certain point. The universe is filled with bodies called asteroids, which gravitate under the control of undiscovered laws. It is they which produce the shooting stars and meteorites. Now, it is easily conceivable that such bodies may fall regularly upon the sun and create heat by the impact. It has been calculated what would be the mass of asteroids capable of thus producing the solar heat, and it has been found that it would form in a year a simple stratum of 20 metres (21.872 yards) at the surface of the sun. It would, at this rate, require more than a million five hundred thousand centuries for the diameter of the solar disk to appear doubled. Our instruments of astronomy are not sufficiently sensitive to enable us to observe an augmentation so slow; thus the hypothesis does not stand in opposition to facts. We should not forget, however, that all this is conjecture, nor can we plume ourselves on having discovered the cause of the phenomena which have been observed.

After the solar heat, it remains to speak of the terrestrial heat, of which we have striking manifestations in volcanic eruptions, in the geysers, those gigantic eruptions of boiling water which are met with in Iceland, to say nothing of the tranquil indications of artesian wells. The laws of these phenomena are not in general completely known, though that of the geysers has been artificially reproduced upon the ingenious theory of Bunsen. What shall it be said is the origin of this terrestrial heat? Everything would lead us to believe that the earth was primitively an incandescent fluid mass, and thus its condition would be analogous to that of the sun. An incessant fall of cosmical matter would maintain its heat and gradually enlarge its mass. Some time or other this supply has failed, and the globe, in cooling, undergone solidification at the surface. Then only did it become the earth.

Thus it will be seen that the generation of heat by the destruction of movement will serve to explain the production of heat in chemical combinations, in the Voltaic circuit, in the organs of living beings—nay, it will furnish no improbable hypothesis of the origin of solar and terrestrial heat. Are we not tempted hence to conclude that *heat is likewise a movement?* We thereby associate the connection we have observed with a great and more general principle than the preceding, *that of the conservation of energy.* In virtue of this principle, if movement ceases in one body, it commences in a neighboring body, so that nothing is lost; all the phenomena of the material world result from an exchange of movement between bodies, one gaining what the other loses.* There is nothing which seems to oppose itself to this generalization; it offers us a picture of what we learn by the senses, and by accepting it as a law, we yield to the sentiment of unity which the Creator has implanted in our souls. But we should be circumspect; we must not allow ourselves to be swayed by imagination, nor surrender reason to the seductive creations of our own invention.

The generation of heat may be a transformation of movement, but what is the intermediary of that transformation? In order to raise the veil which conceals from us the mystery of creation, is it sufficient to say that matter transmits

* The statement requires limitation. It cannot be said that the motion or energy of a cannon ball is all transferred to the side of the ship which it penetrates—a large part is expended in making the hole, another portion in producing the noise of the percussion. and the remainder in generating heat.—J. H.

movement to matter, and to imagine a species of movement constituting heat? Never did savant, who had painfully learned to observe what surrounds him, entertain that thought. For him, the cause of heat is of the same order with that of the fall of bodies to the surface of the earth. It is a force, an abstract principle, which it is not his mission to fathom. And if, having become philosopher, he aims to ascend higher in the scale of causes, he must advance with an extreme sagacity, under the penalty of encountering the most mortifying failures. Few men are endowed with those qualities of mind which are congruous to the philosopher, and those who carry into this rugged enterprise the science and the modesty of the sage are apt to arrive, in their conclusions, at principles of the purest spiritualism.

PRINCIPLES OF THE MECHANICAL THEORY OF HEAT.

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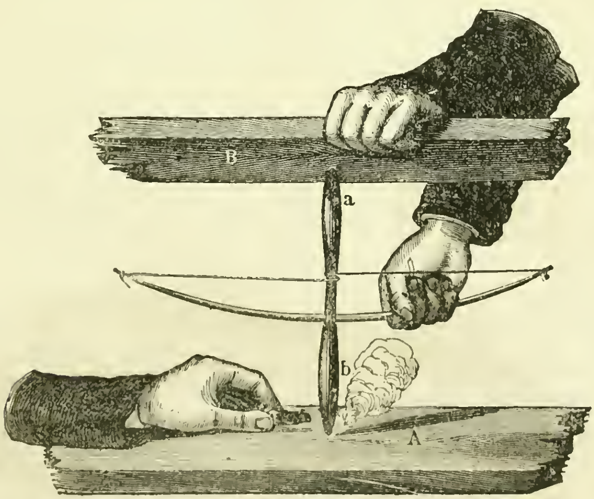
[COMMUNICATED BY THE AUTHOR, IN GERMAN, TO THE SMITHSONIAN INSTITUTION, FROM HIS LEHRBUCH DER PHYSIK, AND ACCOMPANIED BY HIS ALTERATIONS AND CORRECTIONS.]

I.—DEVELOPMENT OF HEAT BY MECHANICAL MEANS.

It is well known that by compression of the air heat is disengaged; and under certain circumstances, as, for example, by means of the fire syringe, may be rendered so considerable as readily to kindle combustible matter. Such development of heat, however, also takes place through the compression of a solid body. To how high a degree the hardest bodies may be heated by violent compression may be observed in the hammering of metals and the coining of money.

But among all mechanical means of generating heat none is more available than friction; and it is this which is almost universally employed when fire is to be provided anew. Every one knows that, for this purpose, uncivilized tribes make use of two pieces of wood—Fig. 1, for example, shows an arrangement of which the Dakota Indians avail themselves. A staff, *a b*, of hard wood, about

Fig. 1.



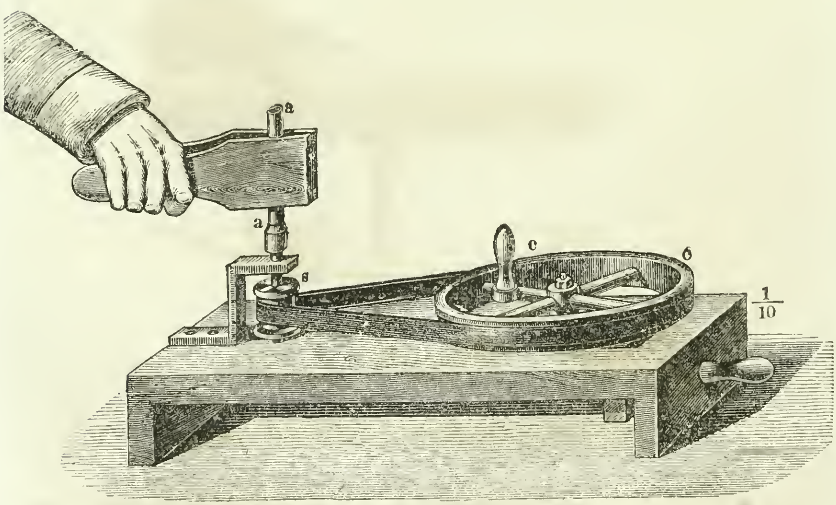
six inches long and somewhat sharpened at both ends, is inserted in a small cavity of the board A, is pressed on the upper end by the board B, and, in the manner represented in the figure, is thrown into rapid revolution. As soon as fire makes its appearance, a piece of tinder, applied by a second person, effects the desired purpose. The kindling of fire by steel and flint depends likewise on the application of heat, developed by attrition, which suffices to kindle to a glow some of the small detached particles of steel, and the now widely-employed

friction match derives its great utility from the heat supplied by a slight rubbing of the kindling matter.

The first scientific experiments on the development of heat by friction were those which Count Rumford instituted in the cannon foundry of Munich, (*Gilbert's annal.* XII, p. 554.) In order that the muzzle of the cannon, which in founding is uppermost, may not become porous, a massive cylindrical piece of metal is cast thereon, usually called "the rejected head," (*der verlorene Kopf.*) In one experiment Count Rumford inclosed the rejected head of a six-pounder in an oblong wooden box, open at the top and filled with water. Through one end of this box was passed, water-tight, the narrow neck which united the head to the cannon; and through the other, also water-tight, the stem of a steel borer. The cylindrical head was 9.8 inches long and 7.75 inches in diameter. The box was charged with $18\frac{3}{4}$ pounds of water; the arrangement being horizontal, the cannon and the attached head were made to revolve by horse-power at the rate of 32 revolutions per minute, the borer, at the same time, being pressed against the end of the head. The temperature of the water was raised after one hour 41° C.; after one and a half hour, 61° C.; after two hours, 81° C. To the wonder of the spectators the water, at the expiration of two and a half hours, was actually boiling. The cylinder and the spindle of the borer were also heated to the same temperature. During the two and a half hours 4,145 grains (about 17 half-ounces) of metal shavings had been turned out.

The experiment not being easily repeated in the form above given, a very elegant and commodious apparatus for exhibiting the same result has been devised by Professor Tyndall. On the axis of rotation of a small wheel (driven by a large one) is screwed a glass tube a, (Fig. 2,) open above and closed below, and having a length of about 12 centimetres, with a diameter of rather more than two centimetres. This tube is not quite filled with water, and is held firmly

Fig. 2.



between two boards of hard wood, provided with semi-circular grooves, the boards being connected by a hinge on one side, and on the other pressed against the tube with the hand. If the fly-wheel be now thrown into rapid rotation, so strong a friction is exerted upon the circumference of the tube that the temperature of the water is quickly raised, as may be easily shown by a thermometer, and finally attains the boiling point. If the tube be made air-tight, with a cork not too firmly fixed, the latter will be thrown out through the elasticity of the enclosed

vapor. Should the experiment require too much time, the tube may be at first filled with warm water.

Sir. H. Davy succeeded in melting two pieces of ice by rubbing them together in a space exhausted of air and cooled below the freezing point, while Mayer first showed (1842) that heat is developed by the friction of water against solid bodies, having, by simple agitation, raised its temperature from 12° C. to 13° C. (*Annal. der Chem. und Pharm.*, May, 1842.)

II.—THE NATURE OF HEAT.

As regards the explanation of the phenomena of heat, two contrary hypotheses have stood, from an early period, in opposition to one another. According to the one, these phenomena proceed from an imponderable element, which, filling up the intervals between the separate atoms of matter, operates as a repulsive principle. Through an augmentation of the particles of heat in a body, its temperature is raised, its constituent atoms still further separated from one another, and thus its volume increased, while cohesion becomes more and more enfeebled and the conditions of aggregation are changed; solid bodies melting, and fluids passing into vapor. This mode of explanation has, till the most recent times, formed the basis of the doctrine of heat as presented in most popular works on the subject, without any positive assertion however, as to the correctness of such a theory. It was employed, in the interim, for want of a better, in order more easily to combine the various phenomena of heat under a common point of view.

The hypothesis of which we speak, namely, that the phenomena of heat result from the quiescent presence of an imponderable calorific element, and which, on that account, we will call briefly the *material theory*, stands opposed to another, according to which heat is the result of a vibratory motion of the minutest particles of bodies, and which thus refers the explanation of the phenomena to mechanical principles; on this account we shall designate the latter in our further discussion of those principles as the *mechanical theory* of heat. It was long ago said by Locke that "heat is a most active concussion of the imperceptibly small particles of a body, which produces in us the feeling we term warmth; the cause of our perception of heat is, in reality, therefore only a motion." There is nothing, in fact, which argues more conclusively in favor of the mechanical explanation of the phenomena of heat than its production through mechanical forces, as exhibited in preceding paragraphs. Certainly, neither the experiment of Rumford nor that of Davy gives the smallest countenance to the conduction of calorific matter from without.

The adherents of the material theory sought to explain the development of heat by the agency of compression, on the assumption that the capacity of bodies for heat decreases with their density, whence a body, when its density is increased, must give out heat. The difference between the specific heat of gases under *constant pressure* and with *constant volume* seemed to argue in favor of this hypothesis till Regnault had proved that the specific heat of a given weight of gas is *independent of its density.* With regard to the development of heat by friction, the material theory endeavored to account for it by assuming that friction is always attended by a corresponding compression, and by the diminution of specific heat thereby occasioned. But more exact investigation showed that the specific heat of the shavings, which fall away from the cannon in boring, differed not sensibly from that of the metal before the boring; while in the experiment of Davy a body is formed, namely, water, whose specific heat is not only not smaller than that of ice, but is actually twice as great. Here, then, the development of heat in nowise admits of being referred to a diminution of the specific heat.

Rumford, as well as Davy, had instituted their experiments with a view to prove the necessity of having recourse to a mechanical explanation of heat. But though they had certainly indicated the right course for answering the question as to the nature of heat, that course was, for the time at least, not followed up;

not so much perhaps because the generality of physicists had declared, in opposition to the two English philosophers, for the material theory, as that the scientific inquirers of that period scarcely occupied themselves at all with the question. Still, however, the material in hand did not cease to accumulate, which, when thrown at a later period into the scale, was destined to give an unquestionable preponderance to the mechanical theory.

The study of radiant heat had taught that every heated body in a colder medium sends forth on all sides calorific rays in like manner as a luminous body distributes rays of light. And as the luminous rays pass through air and other transparent bodies, without communicating to them the property of luminosity, so the rays of heat traverse the air and other diathermanous substances without imparting to them any sensible warmth. The rays of heat are then only converted into perceptible heat when they are absorbed by some body upon which they strike, in the same way that certain bodies (phosphorus, for instance) become themselves luminous under the influence of strong rays of light.

Like the rays of light, the rays of heat are propagated with a velocity which, in relation to terrestrial distances, may be termed instantaneous. They follow the same laws of reflection and refraction as the rays of light. In the rays of heat just such differences appear as those which, in the case of the rays of light, determine the diversity of colors. In a word, it is now fully recognized that the rays of light and heat are, in their nature, identical, and that if any modification distinguishes them, it can only be of a quantitative nature; whence it follows that the phenomena of light and heat must be referred in principle to the same explanation. Since, then, in regard to the phenomena of light, the theory of vibration has triumphantly vindicated its claims against the theory of emanation, no doubt can any longer be properly entertained that the phenomena of heat also are to be referred to mechanical principles.

A body is luminous when its several atoms oscillate with a sufficient degree of intensity and velocity about their position of equilibrium. These atomic vibrations call forth in the surrounding ether an undulatory movement, by which the rays of light are propagated, and hence many analogies exist between sound and light. While sound is generated through the vibratory motion of elastic bodies, light arises from a far more rapid oscillatory motion of the minutest or ethereal particles of matter. As sound is propagated through an undulatory movement of the air, so is light through an undulatory movement of the ether. Like the diversity of tones, so the diversity of colors arises from a difference in the duration of the oscillations of the conducting medium. But, seeing that the rays of light and of heat emitted by a body in combustion are identical, can we avoid the conclusion that the cause of its light and its heat is the same; that *the heat of bodies proceeds, also, only from an oscillatory movement of its atoms?*

Perhaps it may be objected that non luminous bodies also emit heat; that the sun's light, as well as electrical light, is accompanied in large proportion by invisible rays of heat. It might hence seem that a difference exists between the rays of light and those of heat. But more exact investigation has shown that it is only a *quantitative* difference which is here in question. The obscure rays of heat are not different in their intrinsic nature from those which are at the same time luminous; there are rays which are endued with a greater amplitude of oscillation than the red, and whose period of vibration, therefore, exceeds the limit to which the organization of the eye restricts its visual perceptions.

Thus the study of radiant heat has led to the same consequences which Rumford and Davy had deduced from their experiments on the production of heat by friction. But, though the majority of physicists shared the views of the two philosophers, and entertained the conviction that the emanation theory was thenceforth untenable, for a long time nothing further was done to bring this question to a decision until some 24 years ago it was again taken in hand with great energy and prosecuted with ardor in various quarters. The first by whom

this important subject was resumed, and who again recalled it to the attention of physicists in a treatise published, in 1842, in the Annals of Chemistry and Pharmacy, under the title of *Observations on the forces of inanimate nature*, was Mayer, a practising physician of Heilbronn.

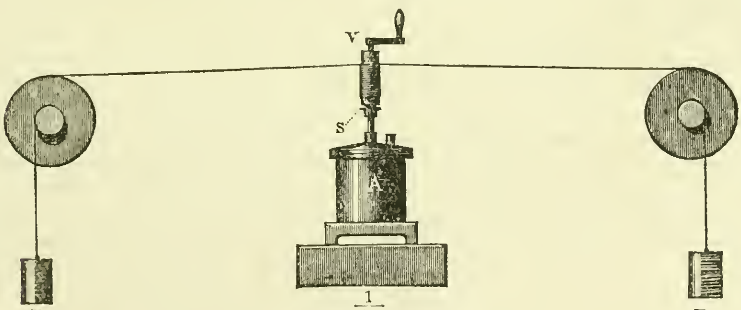
III.—THE MECHANICAL EQUIVALENT OF HEAT.

Mayer first enunciated the idea that, as a definite proportion universally exists between cause and effect, there must always, in the production of heat by mechanical means, be an invariable proportion between the heat generated and the mechanical power consumed for that purpose; and, in fact, he thus early established, with closely approximate exactness, the mechanical equivalent of heat. This was, at a later period, still more accurately determined through the researches of Joule and Hirn.

In 1843 the observation was made by Joule (Phil. Mag., vol. xxiii) that, in the passage of water through a narrow tube, heat is generated, and that a mechanical power of 770 foot-pounds* is consumed in raising the temperature of one pound of water to 1° F., a result which, as we shall see, is not very different from that obtained by compression of the air.

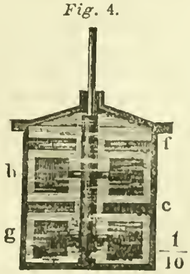
Joule sought, also, to ascertain by other methods the proportion of the heat generated by friction to the mechanical power thereby expended. In a copper vessel (A, Fig. 3,) a paddle wheel, whose construction is represented

Fig. 3.



in Fig 4, was so disposed as to be capable of revolving around a vertical axis. Eight paddles of thin plate, at an angle of 45° with one another, are placed at the height h, eight others at the height g. They move between metallic plates, which are fixed to the wall of the vessel; four of these plates standing at right angles to one another, being at the height f, and four others at the height c.

Fig. 4.



The vessel A, which stands on a wooden pedestal, is filled with water, and the revolution of the paddle-wheel is effected, in the manner represented in the figure, by means of the weights B and D, which by their descent co-operate in communicating motion to the axis of the wheel, and have a fall of about 63 inches. After these weights had reached the floor, by withdrawing the peg s, the connection of the cylinder V with the axis of rotation of the paddle-wheel was severed, the weights B and D were again wound up,

* A foot-pound is the power developed in the fall of a weight of one pound through a height of one foot. An English unit of heat is the quantity required to raise a pound of water one degree Fahrenheit. A kilogram-metre is the power developed in the fall of a kilogram (2.204 pounds) through one metre. A French unit of heat is the quantity required to raise one kilogram of water one degree centigrade.

and the same operation was repeated. After this had been done 20 times the elevation of the temperature produced by the above means in the water of the reservoir A was measured, and was found to amount to nearly 0°.6 F. The mechanical power expended in the production of this effect is obtained by multiplying the weights by the total distance through which they have fallen, with allowance, however, for the acceleration with which, each time, they have descended to the floor.

In the mode here described Joule has conducted a long series of researches, and calculates, as a mean after the application of the necessary corrections, that an expenditure of power equivalent to 773.64 foot-pounds develops under the above circumstances as much heat as is required to raise the temperature of one pound of water 1° F., or, in other terms, that *a unit of heat* (French) *is the thermal equivalent of a mechanical expenditure of power of* 425 *kilogram-metres.*

The friction of an iron paddle-wheel in quicksilver gave 776.3 foot-pounds, and the friction of cast-iron plates with one another 774.88 foot-pounds as the expendture of power which is necessary to raise the temperature of one pound of water 1° F.

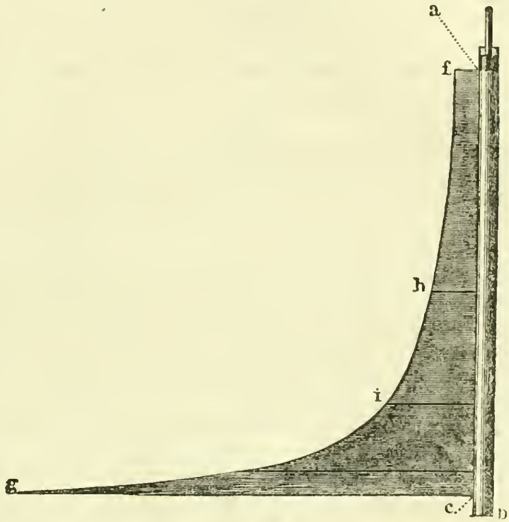
A not very different result was obtained by Joule when he compared the quantity of heat set free in the coils of an electro-magnet rotating between strong magnetic poles, with the mechanical power necessary to produce this rotation, (Phil. Mag. vol. xxiii.) For determining the heat developed in the coils of the rotating electro-magnet, the latter was introduced into a glass tube in such a manner that the interval between the magnet and the glass wall formed a vessel closed on all sides, which was filled with water. Through the heat developed by the rotation of the electro-magnet, the temperature of this water was raised, and the increase of temperature carefully ascertained. In order to determine the mechanical power required to produce the rotation, a string was wound around the prolongation of the axis of rotation, and the revolution of the magnet effected by a weight suspended to the string. From this experiment Joule computed that, for the production of an amount of heat capable of raising one pound of water 1° F. a mechanical power of 838 foot-pounds is requisite, and thus the *unit of heat corresponds to an expenditure of power of* 460 *kilogram-metres.*

To the same physicist we owe an experiment for determining the mechanical equivalent of heat through that which is liberated by compression of the air, (Krönig's Journal, iii). Into a copper reservoir A, 12 inches in length, 136½ cubic contents, ¼-inch thickness of wall, by means of a compression pump screwed to it, air was pressed, as into the bulb of an air-gun, until an elastic force of nearly 22 atmospheres was attained. During this operation the copper reservoir, together with the pump, was immersed in a vessel which held 45 pounds 3 ounces of water. By 300 strokes of the piston the air in the vessel was condensed from 1 to 21.654 atmospheres, and so much heat was thereby developed that the temperature of cool water rose 0°.645 F. This increase of temperature, however, did not arise alone from the compression of the air, but also from the friction of the piston. To eliminate this last, the tube through which the air had been introduced was closed, and it was found that, through 300 strokes of the piston, which now were not attended by a compression of the air in the reservoir, the temperature of the cool water was raised 0°.297 F. By this first experiment, therefore, on computing the results of compression of the air, an elevation of temperature of 0°.348 F. is given.

After making the necessary reductions and corrections, it now resulted that through the compression of 2956 cubic inches of dry air, of atmospheric density, into a space of 136.5 cubic inches, such a quantity of heat was developed as was necessary to raise the temperature of one pound of water 13°.628 F. This is equivalent to the quantity of heat required to raise the temperature of 3437 grams of water 1° C.

Let us now seek to determine the mechanical power which is required in order to compress 2956 cubic inches of air, of atmospheric density, to a 21.654-fold density. For this purpose we will conceive the quantity of air just mentioned to be contained in a tube *a b*, (Fig. 5,) which is supposed to be 21.654 feet long, and to have such a transverse section (11.376 square inches) that the contents of a portion of this tube one foot long shall be equal to the contents of the vessel A, (136.5 cubic inches); thus the above compression will plainly ensue if we force a piston from the upper end *a* down to the point *c*, which is situated one foot above the bottom of the tube. If now lines be drawn at different points of the tube perpendicular to its axis, and of a length always proportional to the pressure under which the included air stands, and if the piston be driven to the point *c*, so that the line *c g* shall be 21.654 times as great as *a f*, the curve *f h i g*, which connects the terminal points of the above lines, will be a portion of an equilateral hyperbola, and the hyperbolic surface *a c g h f* will represent the power which must have been employed in pressing the piston down from *a* to *c*. Let us denote *gc* by *y*, *b c* by *x*, and *b a* by *x′*; thus the contents of the surface in question will be $H=x \cdot y \cdot \log \text{nat} \frac{x'}{x}$ and if $x=1$ $H=y \cdot \log \text{nat}\, x'$, or

Fig. 5.



$$H=2.3026 \cdot y \cdot \log x' \qquad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

if *log* represent the common logarithm referable to 10 as a base. By the test of experiment the barometer stood at 30.2 English inches, which makes on the transverse section of our tube 168.5 pounds. The line *f a* thus represents to us the pressure 168.5, but *g c* the pressure $21.654 \times 168.5 = 3648.7$. Let us now put in equation (1) $x'=21.654$ and $y=3648.7$; we shall thus have

$$H=2.3026 \times 3648.7 \log 21.654=11220 \text{ foot-pounds,}$$

as the expenditure of power which is required to compress 2956 cubic inches of air of atmospheric density into a space 21.654 times smaller, whereby, as has been seen 3.437 units of heat are developed.

Hence, according to these experiments, 3437 units of heat are the thermic equivalent for an expenditure of power of 11220 foot-pounds, or 1552 kilogram-metres. *In order, therefore, to produce one unit of heat through compression of the air, an expenditure of power of* 451 *kilogram-metres is needed.*

For the purpose of measuring the absorption of heat which results from the discharge of compressed air, the vessel A, after the air had been compressed in it to 22 atmospheres, was placed in a reservoir containing 21 pounds of water. As the compressed air was now allowed to escape from the vessel A through a leaden pipe, the temperature of the surrounding water was found to be lowered 4.°1 F. With due regard to all necessary corrections, it may be hence computed that the quantity of heat which disappears by the discharge of the air from

the vessel is perhaps just as great as that which is developed in the vessel through the compression of the air. In this experiment the escaping air has to overcome the resistance of the atmosphere, and thus to perform a mechanical work.

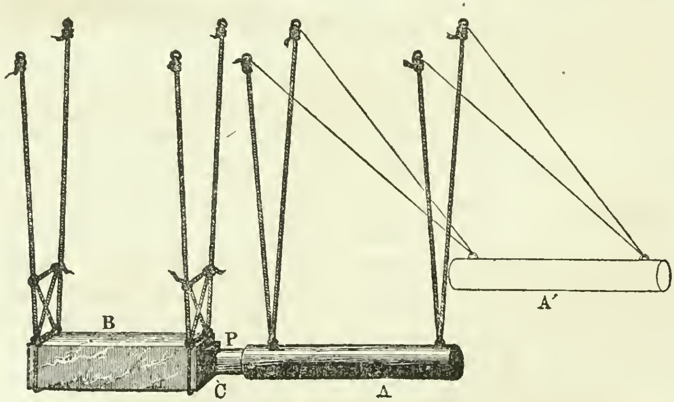
In another series of experiments, to the vessel A, in which air had been compressed to 22 atmospheres, was screwed, by means of a short metallic pipe, an equally large vessel B, exhausted of air, and after both vessels, A and B, had been placed in the same reservoir, holding $16\frac{1}{2}$ pounds of water, a suitably adapted cock was opened, so that half of the air compressed in A could flow over into B. Through this process no observable change of temperature was produced in the water surrounding the vessels A and B, whence Joule draws the conclusion that *no change of temperature occurs when air expands in such a way as to create no mechanical power.*

When the two receivers A and B were placed in separate vessels of water, a lowering of temperature of 2°.36 F. was observed in the vessel which contained the receiver A, out of which flowed the compressed air, while the water which surrounded the receiver B, into which the air flowed, acquired a nearly equal elevation of temperature.

Hirn, also, (*Théorie méchanique de la chaleur*, Paris, 1865,) has made a series of experiments for the determination of the mechanical equivalent of heat, among which we adduce that on the development of heat through the compression of lead as being distinguished at once for its simplicity and conclusiveness.

A cylinder A, of wrought iron, 350 kilograms in weight, which we will call the hammer, is suspended by two pairs of strings about three metres in length, as is shown by Fig. 6. Opposite to this cylinder is suspended in like manner

Fig. 6.



a prismatic block of sandstone, of the weight of 941 kilograms, which we will term the anvil, and which is furnished on the side opposed to the hammer with an iron plate C. Between the hammer and anvil is placed a cylindrical piece of lead P, having a weight of 2.948 kilograms, and supported by a light wooden holder, (*Holzgabel.*) This piece of lead is in part hollowed out in the direction of its axis. Its temperature before the experiment was ascertained by means of a thermometer temporarily introduced into the cavity to be 7°.87.

The hammer was now drawn back by a pulley until it reached the position A′, and then again released. In recovering its position of equilibrium, it delivered a strong blow upon the lead, which compressed and heated. Yet was not the entire living force of the falling hammer spent in the compression of the lead; for, after impact, the stone block and iron cylinder were again driven somewhat apart. According to an experiment of this kind, the height of fall of the

hammer was 1.166 metre; the recoil of the same after impact 0.087 metre; the recoil of the anvil after impact 0.103 metre. Hence the living force which the iron hammer had attained in falling was,

$$L=350 \cdot 1.166=408.100 \text{ metre-kilograms};$$

but the living force with which hammer and anvil after the blow recoiled from one another was,

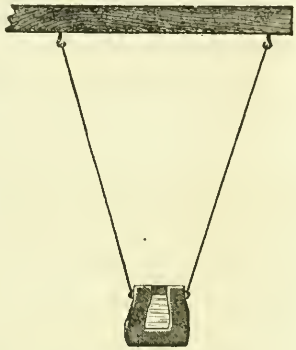
$$l=0.103\ (941+2.95)+0.087 \cdot 350=127{\cdot}677 \text{ metre-kilograms};$$

the living force, therefore, expended in the compression of the lead is,

$$L-l=408.100-127.677=280.423 \text{ metre-kilograms}.$$

In order to determine the quantity of heat which was developed through the compression of the lead, the latter, after receiving the blow, was quickly withdrawn from between the hammer and anvil, and by means of two threads, which had been already attached to it, was suspended in the manner shown at Fig. 8. Into the cavity of the compressed piece of lead, 18.5 grams of water at 0° C. were poured, and the temperature thereof, which very quickly became the same with that of the lead, was ascertained by means of an immersed thermometer. This temperature was:

Fig. 8.



4 minutes after the impact	12°.10
8 minutes after the impact	11°.75

Thus in four minutes, from the end of the fourth minute to the end of the eighth, the cooling amounted to 0°.35. If we assume, now, what may at least be accepted as an approximation, that the rate of cooling, during the first four minutes after the blow, was maintained during the following four minutes, we have $11.75 : 0.35=12.1 : x$; whence results $x=0.36$. Since, therefore, the temperature of the lead had, at the moment of compression, been $12°.10+0°.36=12°.46$, the calefaction from the blow would be $12°.46-7°.87=4°.59$; consequently, the quantity of heat developed through the collision is, $4°.59 \cdot 2.948 \cdot 0.03145+12.46 \cdot 0.0185=0.656$ units of heat, since 0.03145 is the specific heat of lead.

If we divide the work spent in the compression of the lead, 280.423 metre-kilograms, by the corresponding quantity of heat, 0.656 thermic units, we obtain the work necessary for producing one thermic unit,

$$\frac{280.423}{0.656}=427 \text{ metre-kilograms}.$$

Instead of this number, however, 425.2 is the result, if the cooling of the lead is not calculated approximately, as above, but by exact formulas.

IV.—EQUIVALENCE OF HEAT AND WORK.

As a mean, there results, from the best experiments which have been made on this subject, 424 metre-kilograms as the mechanical equivalent of heat, or, to use a more accurate expression, the *work equivalent of the unit of heat;* and the quantity of heat A, which corresponds to the unit of work, is

$$A=\frac{1}{424}=0.002358 \text{ units of heat};$$

that is to say, the caloric equivalent of the work unit is 0.002358 units of heat; by the expenditure of one metre-kilogram, therefore, 0.002358 units of heat may be generated.

But if heat can be generated by mechanical power, *so inversely must heat be competent to produce mechanical effects*, and, in fact, according to the mechanical theory of heat, one heat unit must be regarded as capable of performing the work of 424 metre-kilograms, or, in other words, for each metre-kilogram of work performed 0.002358 units of heat must be expended.

This equivalent results, in the first place, theoretically, if we assume as known the ratio of the specific heat of gases, under constant pressure and in constant volume, as well as the coefficients of the expansion of the gases. One cubic metre of air at 0°, under ordinary atmospheric pressure, weighing 1.293 kilogram must be heated to 273° C., if, with unaltered volume, its elasticity be augmented to two atmospheres. But for this are required,

$$273 \times 1.293 \times 0.1686 = 59 \text{ units of heat,}$$

since 0.1686 is the specific heat of air with constant volume. But if one cubic metre of air at 0°, with atmospheric pressure, be raised to the temperature of 273° C., while, with constant pressure, it is free to expand, its volume will be increased to two cubic metres, and the quantity of heat necessary, therefore, is

$$273 \times 1.293 \times 0.2377 = 83 \text{ units of heat,}$$

since 0.2377 is the specific heat of air with constant pressure. The difference, $83 - 59 = 24$ units of heat, is thus necessary, over and above the increase of temperature, to expand the gas, under constant pressure, to double the volume.

Let us now inquire into the quantity of mechanical work thereby performed. Let us conceive the above-mentioned quantity of air enclosed in a hollow cylinder, having a transverse section of one square metre, and confined above by a moving piston, which, at its starting point, is elevated one metre above the immovable floor. On this piston the atmosphere bears with a pressure of 10333 kilograms. If the enclosed air, with unaltered pressure, be now expanded to a double volume, it must necessarily push the piston one metre, which corresponds to a mechanical work of 10,333 kilogram-metres. Thus to execute a mechanical work of 10333 metre-kilograms, 24 units of heat are necessary; hence one unit of heat corresponds to a mechanical work of $\frac{10333}{24} = 430$ kilogram-metres, a result which so nearly coincides with that obtained in the inverse way, namely, by conversion of mechanical work into heat, that no doubt of the complete reciprocity between mechanical work and heat can longer exist.

The experiments and observations above recited have served to establish the proposition that "*in all cases in which work is produced by heat, a quantity of heat proportional to the work produced disappears or is consumed, and that inversely the same quantity of heat may be generated by the expenditure of an equal amount of work;*" a proposition which is usually received as the first law of the mechanical theory of heat, and which, with this degree of precision and generality, was first enunciated by Clausius. It is the proposition which forms the starting point of the mathematical development of the mechanical theory of heat, and in regard to it the learned have furnished us with a series of articles in Poggendorff's *Annalen*. These articles, accompanied by annotations by Friedrich Vieweg and son, have recently (1865) appeared at Brunswick in a single volume.

Besides Clausius; Holzmann, Clapeyron, W. Thomson, Rankine, and others have occupied themselves with the mathematical development of the mechanical theory of heat, while Zeuner may claim the merit of having collected in a clear and comprehensive form the leading characteristics of the theory and of having illustrated it by manifold applications, (*Grundzüge der mechanischen Wärmetheorie*, 1st edition, 1860, 2d, 1866, Leipzig.) Another highly acceptable work on this important subject is the *Théorie mecanique de la chaleur*, by Hirn, (2d edition, Paris, 1865,) in which, together with the analytic development, the experimental part is very thoroughly treated.

In all these writings the mechanical theory of heat is developed, as it needs must be when a general and complete solution of the problem is contemplated, through a certain amount of the higher mathematical analysis. In what follows, however, I shall endeavor to set forth at least the most important principles thereof in an elementary form, and, by the application of these principles to saturated vapors, to show some material consequences of their action. I shall hope, thereby, not only to communicate a right idea of the nature and signification of the theory in question to those who are deficient in a knowledge of the differential and integral calculus, but also to supply to those who may be provided with that learning, a sort of introduction or preparation for the more thorough study of those doctrinal difficulties which are apt to oppose themselves at the entrance upon such an investigation. But before proceeding to a nearer consideration of the grounds of the mechanical theory of heat, we will examine more definitely the *loss of heat*, corresponding, in some particular cases, to the *performance of work*.

V.—DISAPPEARANCE OF HEAT THROUGH THE PERFORMANCE OF WORK.

By a large number of experiments directed to the subject under consideration, Hirn has shown that in steam-engines a quantity of heat disappears directly corresponding to the work executed, he having employed with that view engines of from 90 to 150 horse-power. The machines with which he experimented were of the expansion order, in which the steam, after it had operated, passed off into a condenser. In order to avoid errors which might arise from water being mechanically carried over by the engine from the boiler, or steam already condensed in the expansion, Hirn caused the machinery to work with overheated steam, which he procured by means of an appropriate apparatus, whereby the vapors proceeding from the boiler were heated, before their entrance into the cylinder, to a definite temperature ascertained by a thermometer.

The quantity of water p which entered, in a second, the vessel for evaporation, and arrived through the machine in the condenser, was ascertained by exact measurement of the quantity of water which, during the space of a whole day, was conveyed by the feed-pump into the boiler, under a uniform working of the machine, and with an unchanged height of water in the boiler. In like manner the quantity of water P immitted each second into the condenser was ascertained by the determination of the quantity of water of condensation discharged during a whole day under a uniform influx.

The quantity of heat given up by the steam condensed during each second, was found in the following manner: If t be the temperature at which the steam is formed in the boiler, then according to Regnault's experiments, the whole quantity of heat which is contained in one kilogram of steam at this temperature more than that contained in one kilogram of water at 0°, is $q_1=606.5+0.305t$ units of heat. But this steam, before its entrance into the cylinder of the steam engine, is heated to the degree of T, whence there is further necessary for each kilogram of steam $q_2=0.5\,(T-t)$ units of heat, if we take, as may be done with approximative correctness, 0.5 as the specific heat of the steam.

The quantity of heat which this kilogram of steam loses, until it is condensed and cooled to the temperature of f degrees, with which the water of condensation leaves the condenser, is thus q_1+q_2-f, and hence the whole quantity of heat, which the quantity of steam p traversing the engine every second gives up, is

$$\begin{aligned} Q_1 &= p\,(q_1+q_2-f), \\ &= p\,[606.5+0.305t+0.5\,(T-t)-f]. \end{aligned}$$

If, now, no heat were consumed by the performance of work in the cylinder the whole quantity of heat Q_1 must be carried over to the condenser, and here serve to raise the temperature of the condensation-water. If i be the temperature at which that water enters the condenser, but f the temperature at which it issues therefrom, then $f-i$ is the quantity of heat which each kilogram of condensation-

water takes up in the condenser, whence the quantity of heat Q_2 which is taken up, in each second, by the condensation-water is $Q_2=P\,(f-i,)$ and thus must $Q_1=Q_2$ if no heat be expended for the work. But experiment shows in fact that Q_1-Q_2 is in nowise equivalent to nothing. In such an experiment, for example, in which the ratio of expansion was 1 : 2, the tension of the steam in the boiler gave a result equal to 4.5 atmospheres, and thus $t=148°.3$. Also,

$$T-t=91°.7$$

$$p=0.34554 \text{ kilograms.} \qquad P=5.84004 \text{ kilograms.}$$

$$f=37°.28 \qquad i=5°.1$$

whence results,

$$Q_1=228.16 \qquad Q_2=187.82$$

$$Q_1-Q_2=40.34 \text{ units of heat.}$$

There had, consequently, been 40.34 units of heat expended for the work done, while the net effect of the machine was found, by Prony's dynamometer equal to 11250 metre-kilograms, and hence there results for one unit of heat consumed

$$\frac{11250}{40.34}=278 \text{ metre-kilograms,}$$

as the practical or net effect.

By another experiment with the same machine, in which the ratio of expansion was 1 : 6, the following values were given:

$$t=152°.2 \qquad T-t=93°$$

$$p=0.23548 \text{ kilograms.} \qquad P=5.8718 \text{ kilograms.}$$

$$f=2°.605 \qquad i=3°.2$$

whence there results

$$Q_1-Q_2=158.81-123.3=30.51 \text{ units of heat,}$$

while the net effect of the machine was found equal to 8700 metre-kilograms, and thus, for one unit of heat consumed, there results

$$\frac{8700}{30.51}=285 \text{ metre-kilograms.}$$

Thus it will be seen from these premises that not only is there really a consumption of heat for mechanical work, but also that the practical effect of steam-engines is very nearly proportional to the loss of heat.

We might, from these investigations alone, calculate the mechanical equivalent of heat, if the practical effect measured were equal to the whole work done by the steam. Let us suppose now that the net effect of the machine amounted to about 70 per cent. of the entire work done by the steam, and we shall have, as the mean of the two above experiments, the mechanical equivalent of heat equal to 400 metre-kilograms.

In like manner Clausius derived from a great number of experiments, which were conducted with steam-engines by Hirn, the number 413 as the mean value for the mechanical equivalent of heat. Now, if we assume the mechanical equivalent of heat equal to 424, it would result from the two experiments, whose details have been given above, that the practical effect of these machines amounts to about 66 per cent. of the whole work done by the steam.

Every process which is of a nature to produce heat can also perform mechanical work; but such work is always attended by a corresponding consumption of heat, or, in other words, the quantity of heat produced by a definite process suffers a corresponding diminution, if together with the generation of heat mechanical effect is produced. This proposition is well illustrated by the electro-magnetic motor. When an electric current traverses the metallic coils of a magnetizing spiral, the wire is heated, and the heat produced, in a given time, in the whole circuit is expressed by the equation

$$w=\cdot k\,s^2 l.$$

where s indicates the quantity of the current, l the total resistance of the circuit, and k a constant factor. The quantity of heat produced, however, is, under like conditions, always proportional to the consumption of zinc in the battery, (local action being of course disregarded.) Were the conducting wire, for instance, so much lengthened that the whole resistance of the circuit would be doubled, and thus raised to $2l$, the quantity of the current and consumption of zinc would be thereby reduced to half, but the heat produced by the current would be

$$w' = k\frac{s^2}{4} \cdot 2l = \tfrac{1}{2} \cdot k \cdot s^2 l = \tfrac{1}{2} w.$$

Thus with the quantity of current and consumption of zinc, the production of heat also would be reduced to half.

Quite otherwise is the result when the diminution of the quantity of the current is produced, not by the augmentation of the resistance to conduction, but by the expenditure of power.

In a previous section of this work it has been seen that the strength of the current, which traverses any electro-magnetic motor in a state of repose, is instantly reduced when the motor begins to rotate, and that the current becomes weaker as the rotation is more rapid. Let us suppose that the burden of the machine be so regulated that the strength of the current of the rotating machine be just half as great as in that at rest, then, with the quantity of current reduced to half, the consumption of zinc will also be reduced to half; but the production of heat will have decreased in a quite different proportion. Since now the strength of the current is $\frac{1}{2} s$, but the resistance the same as in the machine at rest, namely, l, we shall have as the quantity of heat produced

$$w'' = \tfrac{1}{4} k \cdot s^2 l = \tfrac{1}{4} w.$$

Thus the zinc consumption reduced to half produces only a quantity of heat reduced to one-fourth; *a part of the zinc-consumption, therefore, is not employed in the production of heat, but in the performance of mechanical work*, or, in other words, for the quantity of heat $\frac{1}{4} w$, an equivalent mechanical work has been performed.

We observe a similar state of things if we investigate the performance of labor by human or animal forces. Animal heat, we know, is generated by a slow combustion, kept up through the process of breathing. For the oxygen which we inspire, carbonic acid and vapor are exhaled; with every breath, therefore, a definite quantity of carbon and hydrogen leaves the body, and the corporeal mass must necessarily undergo a corresponding diminution; a diminution which, if not determinable by weight for every breath, is readily so for an interval of a few hours. This loss of material in the process of breathing is replaced through the reception of food.

But the proportion between the production of heat and the consumption of corporeal matter is quite different, according as the person remains perfectly at rest, or is engaged in the performance of some more or less considerable labor. The production of heat and consumption of oxygen, and, consequently, the bodily diminution of weight, are at a minimum, if the individual continues for some time sitting or lying in complete inactivity. If he perform, on the contrary, some strenuous labor, both the consumption of oxygen and the reduction of weight will be found in the same space of time to have been much more sensible. Through the accelerated breathing and more rapid pulsation the production of heat in the body is undoubtedly augmented, but it results from the principles of the mechanical theory of heat that the development of warmth cannot be taken as directly proportional to the consumption of oxygen, but that the increased interchange of matter in the body serves only in part for the production of heat, while the rest has been spent in the producing mechanical effect.

The correctness of this proposition has been verified by Hirn in a series of

carefully conducted experiments. With this view he occupied a small hermetically-closed chamber, constructed of deal-boards, and lighted by a glass window, the contents of which chamber measured about four cubic metres. At one end of this structure was a chair on which he sat when occupied with the development of heat under conditions of repose. At the other end was a tread-wheel, the axis of which passed, but so as to be air-tight, through the wall, and was connected on the outside with such an apparatus that by the turning of the wheel a mechanical work was executed. The quantity of this labor performed at each revolution of the wheel is manifestly equal to the lifting of the bodily weight of the experimenter to a height represented by the circumference of the wheel. By means of a counter adapted to the axis of the tread-wheel, the number of revolutions in a given time could be counted, while the quantity of external mechanical work done in an hour could be determined with great accuracy.

Before the mouth of the experimenter a valve apparatus was attached, from which a caoutchouc tube was carried to a gasometer which furnished the air required for breathing, while a second tube of like material passed to another gasometer which received the exhaled gases; these, as well as the air inhaled, were carefully analyzed. The chamber was placed in the midst of a larger apartment, the temperature of which varied but little and slowly. Sensitive thermometers gave the temperature of the air both without and within the chamber. If, during repose or labor, the interior thermometer had become stationary, its indication was noted, and the valve apparatus placed before the mouth, so that the consumption of oxygen during an unaltered condition of the experimenter might be ascertained.

It is clear that if the interior thermometer ceased to rise, the loss of heat in the chamber through its walls had become equal to the quantity of heat which the experimenter developed. By a series of preliminary experiments, Hirn had determined what quantity of heat must be developed within the chamber, in order to maintain within and without definite differences of temperature. With this view a flame of hydrogen gas, supplied by a constant stream, was suffered to burn in the interior of the chamber. For a definite magnitude of the flame, when the condition of equilibrium is attained, a determinate difference of temperature within and without the chamber is established; and when the quantity of hydrogen consumed in a given time is ascertained, we can calculate what quantity of heat has been developed in that time, since we know how many units of heat are developed by the burning of one gram of hydrogen, (§ 277.) From the repetition of these experiments for different sizes of flame, Hirn obtained the empirical law on which depends the excess of temperature in the interior from the quantity of heat there developed, and he could thus deduce, in later experiments, from the observed difference of temperature the quantity of heat developed by the experimenter.

When, during such an experiment, Hirn occupied the chamber, he found that, with absolute rest of his person, 29.65 grams of oxygen were consumed in an hour, while the development of heat during that time amounted to 155 units of heat, (*calorics*,) being $\frac{155}{29.65}$, or 5.22 units of heat to one gram of oxygen. When, on the other hand, the experimenter labored on the tread-wheel, so that the work done in an hour amounted to 27448 metre-kilograms, the consumption of oxygen in that space of time was 131.74 grams, while the quantity of heat developed, as indicated by the thermometer, amounted to 251 units.

In the state of rest, however, the 131.74 grams of oxygen consumed would be $131.74 \times 5.22 = 687.68$ units of heat, and thus 436.68 would be exhibited more than had in fact been developed; but instead of the vanished 436.68 units of heat, work had been done, partly without, on the tread-wheel, and partly within, in the organism itself.

In a second experiment the external work done amounted in an hour to 20750 metre-kilograms, while 112.2 grams of oxygen were consumed, and 255.6 units of heat produced. These 112.2 grams of oxygen would, in a state of rest, have afforded 585.7 units of heat; thus $585.7-255.6=330.1$, and, consequently, 330.1 units of heat more than the experiment shows. These 330.1 units of heat have been hence expended in mechanical work; but the quantities of heat consumed in both experiments for mechanical work, 436.68 and 330.1 stand, in fact, in relation to the external work done; for, from the proportion

$$330.1 : 436.68 = 20750 : x$$

results $x=27450$, which coincides quite nearly with the observed number 27448.

A strong horse, when he remains standing at rest in a stable, is amply nourished with 7.5 kilograms of hay, and 2.5 kilograms of oats, which, together, contain 4 kilograms of carbon. But as soon as the horse is put to work this amount of nourishment does not suffice; it is necessary, if he is to be kept in good condition, to add 5.5 kilograms of oats, which contain 2.2 kilograms of carbon. On a day of work, therefore, 6.2 kilograms of carbon are supplied to this animal's body.

As the power of one horse executes, in a second, a work of 75 metre-kilograms, the work done in 8 hours equals $75 \cdot 60 \cdot 60 \cdot 8$, or 2,160,000 metre-kilograms, According to the experiments of Favre and Silbermann, by the oxidation of one kilogram of carbon 8080 units of heat are developed, which corresponds to a mechanical work of $8080 \cdot 424$, or 3,425,920 metre-kilograms. Hence the day's work performed by a horse, 2,160,000 metre-kilograms, corresponds to a consumption of

$$\frac{2160000}{3425920}=0.63 \text{ kilogram of carbon.}$$

Of the nutriment, therefore, supplied to the horse's body for a day's work, namely, 6.2 kilograms of carbon, only 0.63, being about $\frac{1}{10}$, is expended for the performance of mechanical labor, the rest being partly used for the sustentation of animal life, for the production of heat, and in part passing unoxidized through the body.

According to Boussingault only 65 per cent. of the carbon introduced into the body is oxidized, while 35 per cent. is given off unconsumed. Of the four pounds of carbon, therefore, which the horse at rest takes for his daily nourishment, only 2.6 pounds, and of the additional 2.2 kilograms of carbon allotted for days of labor only 1.4 kilogram arrive at oxidation in the body of the animal. Hence in a day of rest there are produced in the horse's body $8080 \cdot 2.6=21008$ units of heat. Of the 1.4 kilogram of carbon, further oxidized on days of labor, 0.63 are consumed in mechanical work, while the remaining 0.77 kilogram $(1.4-0.63)$ go to supply the increased heat production of $8080 \cdot 0.77=6221$ units. Thus on a day of work the heat developed in the horse's body ascends to 27229 units, while only $8080 \cdot 0.63=5090$ units of heat are converted into work.

VI.—ELEMENTS OF THE MECHANICAL THEORY OF HEAT.

If we conceive heat to be a molecular movement, the temperature of a body is to be taken as proportional to the vis-viva inherent in the material atoms which move in some way, perhaps vibrate around their position of equilibrium. An increase of temperature consists, therefore, in an augmentation of this vis-viva, and hence in an enhanced velocity of the molecular movement.

Not all the heat, however, added to a body contributes to the raising of its temperature; and hence not all the heat added to it is employed in the augmentation of the active vis-viva of its molecular vibrations, for a part of the heat may, under conditions, be consumed in order to overcome the molecular forces which exert an action between the several atoms of the body and present an impediment to their free movement. This last heat, which Clausius denotes as that consumed in internal work, is usually called latent heat.

If we designate the free heat of a body by T, the latent heat, which it may contain, by L, the whole quantity of heat in the body will be $U=T+L$.

W. Thomson has proposed for this quantity, first introduced into the doctrine of heat by Clausius, the name of *energy of the body;* but Clausius has recently designated the two components of U as store of heat, T, (*Wärmeinhalt,*) and store of work, L, (*Werkinhalt.*)

If now so much heat be added to a body of the temperature t and the volume v, in which the collective quantity of heat, U, (energy,) is contained, that its temperature be increased by t'°, its volume by v' cubic metres, and the quantity of heat contained within it by U', it will not answer to ascribe to it this quantity of heat U', because through the simultaneous expansion of the body by v' an external work has been done which consumes a corresponding quantity of heat.

If p be the pressure under which the body stands, then the external work which corresponds to the enlargement of volume v' will be $p\,v'$, supposing the pressure p to remain unaltered during the whole expansion; but the quantity of heat corresponding to that work is $w=A\,p\,v'$. Thus the quantity of heat which must be supplied to the body in question in order to increase its temperature from t to $t+t'$, its volume from v to $v+v'$, and the heat contained in it from U to $U+U'$ is,

$$q=U'+A\,p\,v' \qquad \text{I}$$

an equation which corresponds to the differential equation

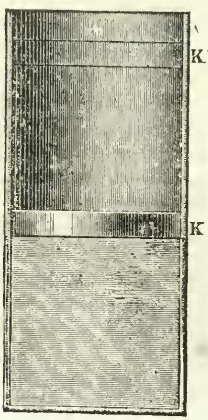
$$d\,Q=d\,U+A\,p\,d\,v \qquad \text{I}\,a$$

in which $d\,Q$ designates the very small quantity of heat which must be supplied to the body, in order for the interior heat of the body to undergo the small augmentation $d\,U$ and its volume to be increased by the small magnitude $d\,v$.

The equation I or rather a differential equation corresponding to it, is the mathematical expression of the *first law of the mechanical theory of heat.* By the help of this equation we can calculate the quantity of heat which disappears through a given change of volume of a body submitted to a given pressure, provided we know the whole work done thereby; which is, however, only the case when we have to do *exclusively with external work* without the accession of any internal work proceeding from molecular forces, and which evades a direct measurement. The first law, therefore, of the mechanical theory of heat suffices only for the solution of correspondent problems when in the magnitude U' of the equation I or in $d\,U$ of the equation I a an internal work is not comprehended, a condition which is only satisfied by bodies of a completely gaseous form.

The following examples will illustrate the application of the first law of the mechanical theory of heat to gaseous bodies. In a hollow cylinder, (Fig. 9,) having a transverse section of one square metre, is situated at the distance of one metre from the bottom an easily movable, but air-tight, piston K; the space of one cubic metre, shut in by this piston, is filled with atmospheric air at 0°, while the pressure of the atmosphere weighs on the piston; and hence the total pressure which tends to sink the piston is 10333 kilograms.

Fig. 9.



If this mass of air, the pressure unchanged, be heated to 273° it will be expanded to double its original volume; the piston, during this expansion, will be thrust one metre higher, and thus be brought into the position K'. The work so done is 10333 metre-kilograms, and the quantity of heat, $A\,p\,v'$, consumed in doing this work is, in that case,

$$\frac{10333}{424}=24.37 \text{ units of heat.}$$

The total heat, q, which must be supplied to a cubic metre of air at 0° and under atmospheric pressure

(1.293 kilograms of air) in order to raise it to a temperature of 273°, while, with pressure unchanged, it is expanded to double its volume, is

$$273 \cdot 1.293 \cdot 0.2377 = 83 \text{ units of heat,}$$

since the specific heat of the air under constant pressure is equal to 0.2377; hence we have $83 = U' + 24.37$, or $U' = 83 - 24.37 = 58.63$.

Thus, of the 83 units of heat which we supply to the 1.293 kilogram of air, in order to raise its temperature from 0° to 273°, while with unaltered pressure it undergoes expansion to twice its original volume, 58.63 units of heat have gone over into this air, while the remaining 24.37 units of heat were expended in doing the work involved in its expansion. In order, then, to raise the temperature of 1.293 kilograms of air from 0° to 273°, while the *volume of the air remains unaltered*, and so no external work is done, only 58.63 units of heat are necessary. The specific heat of the air under constant pressure stands, therefore, to the specific heat of the air under constant volume as 83 : 58.63, or as 1.415 : 1; while this ratio has been found, in another manner, to be as 1.421 to 1.

We have here supposed the mechanical equivalent of heat to be known, and from this derived the ratio of the specific heat of the air under constant pressure and constant volume, while in § 4 the inverse process was followed, inasmuch as we assumed this last ratio to be known, and from thence derived the mechanical equivalent of heat.

The quantity of heat q which must be supplied to a body in order to raise its temperature from t to $t+t'$, to increase the heat contained in it from U to U+U′, and to enlarge its volume from v to $v+v'$, is by no means the same under all circumstances; for, with a like condition at the beginning and the ending, the work done during the transition from the first to the last may be very different. The equation I is properly constructed only for a special case; for the case, namely, in which the pressure p remains unaltered while the volume of the body enlarges from v to $v+v'$. When the pressure p is variable the equation I can only so long be recognized as valid, as the augmentation v' of volume is small enough to be regarded as the differential of space; as is the case with the differential equation I a corresponding to the equation I.

But when, with a variable value of p, the enlargement of volume v' is somewhat considerable, the work done during the expansion from v to $v+v'$ can no longer be expressed simply by the product pv'. Here the case presents itself when a higher method of calculation must indispensably be put in practice, if the object be an exact expression for the work done. With elementary expedients we can, in such cases, only attain, by special calculations, to approximative values.

Let us proceed, in order to make this more intelligible, to the consideration of a special case. We have above calculated the quantity of heat q which is requisite to raise a cubic metre of air of 0° and sustaining atmospheric pressure, to 273°, while the air expands under an unvarying pressure to double its original volume. Here is the final condition: two cubic metres of air of 273° temperature and an elasticity of one atmosphere. The same final condition can, however, be also reached, beginning with the same incipient condition in another manner. Let the piston (Fig. 9) be again in its original position K, and, under it in the cylinder, one cubic metre of air at 0° sustaining atmospheric pressure, the burden of the piston being thus 10333 kilograms. If this weight be now slowly and regularly diminished to one-half, the air will gradually expand and push the piston upwards; thus there should, in the first place, be so much heat supplied to the air that, with an unchanged temperature of 0°, the piston is heaved upwards one metre, and the volume of air therefore doubled.

The quantity of heat necessary for this is only to be determined by higher processes of calculation, but an approximate value may be obtained in an elementary way. Let us conceive the pressure p, which weighs upon the piston

when it occupies the position K, to be not constantly diminished, but to be withdrawn at suitable intervals, each time some $\frac{1}{20}p$, the pressure bearing upon the piston will then conform to the succession of values exhibited in the first column of the following table under D:

D	H	h	h D
$\frac{19}{20}p$	$\frac{20}{19}l$	$\frac{20}{19.20}l$	$\frac{1}{20}pl$
$\frac{18}{20}p$	$\frac{20}{18}l$	$\frac{20}{18.19}l$	$\frac{1}{19}pl$
$\frac{17}{20}p$	$\frac{20}{17}l$	$\frac{20}{17.18}l$	$\frac{1}{18}pl$
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
$\frac{11}{20}p$	$\frac{20}{11}l$	$\frac{20}{12.11}l$	$\frac{1}{12}pl$
$\frac{10}{20}p$	$\frac{20}{10}l$	$\frac{20}{10.11}l$	$\frac{1}{11}pl$

If we denote by l the height of the piston above the floor, when it occupies its position at the commencement, it will ascend by the succession of diminished pressures to the respective heights indicated in the second column. The height, therefore, through which the piston rises at each succeeding diminution of pressure has the value given in the third column under h.

Without sensible error, we can now assume that the pressure of the enclosed mass of air acting upon the piston from beneath remains unaltered during its ascent through one of the heights indicated in the third column under h. For this pressure we may assign, as a first approximation, the value of D, standing in the first column in the same horizontal row, which we must multiply into the corresponding value of h, in order to obtain the value of the work which is done in the ascent of the piston through one of the divisions in question. The products thus obtained are grouped together in the last column under h D.

The total work which is done while the piston rises, under the indicated circumstances, from K to K′, is therefore the sum of the values exhibited in the last vertical row of the above table, namely,

$$L'=\left(\frac{1}{11}+\frac{1}{12}+\frac{1}{13}+\frac{1}{14}+\frac{1}{15}+\frac{1}{16}+\frac{1}{17}+\frac{1}{18}+\frac{1}{19}+\frac{1}{20}\right)pl.$$

The sum of the fractions standing between parentheses, which is most readily obtained if they be changed into decimal fractions and then added, is 0.668, and since $p=10333$, while l is 1 metre, there results for the total work $L'=0.668\cdot 10333=6902$ metre-kilograms.

This value of the total work is, however, manifestly too small; for we have multiplied each of the heights consigned to the third column into the pressure which acts against the under surface of the piston when it stands at the upper end of the corresponding division. If we multiply each of the values of h into the pressure which acts against the piston when it is at the lower end of the division, the result will be

$$L''=\left(\frac{1}{10}+\frac{1}{11}+\frac{1}{12}+\frac{1}{13}+\frac{1}{14}+\frac{1}{15}+\frac{1}{16}+\frac{1}{17}+\frac{1}{18}+\frac{1}{19}\right)pl;$$

hence $L''=0.718pl$, or putting for p and l their numerical value, $L''=0.718.10333=7419$ metre-kilograms. But this value is evidently too great; the true value of the total work L is, at any rate, very nearly equal to the mean between L′ and L″; hence

$$L=\frac{L'+L''}{2}=\frac{6902+7419}{2}, \text{ or } L=7160 \text{ metre-kilograms};$$

and the quantity of heat necessary for the performance of this work is,

$$w'=\frac{L}{424}=\frac{7160}{424}=16.8.$$

The exact value of w' is found by equation (1) in § 3, if we take $y=10333$, and $a'=2$; the result is then $L=2.3026 \cdot 10333 \cdot \log 2=7153$, a value from which that obtained above in an approximative way differs but inconsiderably.

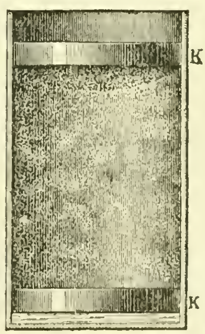
When, now, the piston has become fixed, so that no further expansion of the air is possible, 58.63 units of heat are necessary to raise the temperature of the included air from 0° to 273°, whereby its elasticity also is enhanced from one-half to one atmosphere. Thus the final condition of the air is exactly the same as in the case above considered, in which the air expanded under a constant pressure. The quantity of heat, however, requisite for the attainment of the final condition in question is, in the last case, only $58.63+16.88=75.51$, while in the first case it was equal to 83.

Thus the quantity of heat which must be supplied to a body, in order that, starting from a given condition, it shall pass over into a determinate final condition, is by no means an invariable magnitude, but is dependent on the magnitude of the mechanical work which is done during that transition.

VII.—APPLICATION OF THE MECHANICAL THEORY OF HEAT TO AQUEOUS VAPORS.

Suppose that at the bottom of a hollow cylinder, of which the transverse section is one square metre, there is a litre of water at 0°, and that directly upon this is placed a piston on which a pressure p is exerted, (Fig, 10.) This pressure p is that which is equal to the elasticity of the saturated vapor of $t°$ C. The table on a following page, contains, according to Regnault's experiments, the values of p for the temperatures given in the first column, p being the pressure which the saturated vapor of the corresponding temperature exerts on one square metre.

Fig. 10.



Let the water under the piston be now heated from 0° to $t°$; it will thus expand to a magnitude which, for our present purpose, may remain unknown. There needs for this elevation of temperature a quantity of heat expressed by $W=t+0.00002t^2+0.0000003t^3$, if we take into consideration the variableness of the specific heat of water; while $W=t$ would be the expression, were the specific heat of water taken as constant and equal to one. Hence the quantity of heat to be taken as a unit is that which is required to raise the temperature of one kilogram (one litre) of water from 0° to 1° C. During this exaltation of temperature from 0° to $t°$ no steam can be formed.

But if we continue the supply of heat, the formation of steam commences, and the steam has forthwith the elasticity of p; it pushes back the piston, and the space made free is continually filled with fresh vapor, until finally all the water is converted into vapor. At this moment the end is attained; the heat which must be supplied to the water of $t°$ during the formation of steam with

constant *pressure*, may be denoted by r. This quantity of heat r is usually called latent heat; for it disappears as regards the thermometer, and during the whole process the temperature t remains unaltered.

The whole quantity of heat which, under the suppositions premised, must be supplied to the water at 0°, in order to convert it into steam at $t°$ and of the corresponding elasticity p, is therefore $Q=W+r$. But according to Regnault's investigations the quantity of heat requisite for the object in question is $Q=606.5+0.305t$; consequently, since $r=Q-W$,

$$r=606.5-0.695t-0.00002t^2-0.0000003t^3.$$

Instead of this value of r, Clausius makes use of the approximate value

$$r=607-0.708t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 1)$$

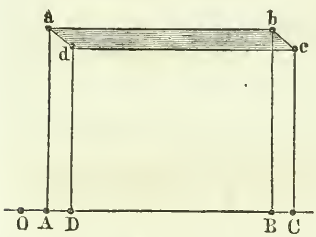
according to which the numerical values of the sixth vertical series of the subjoined table are calculated, while the fifth column contains the corresponding values for Q.

If the whole quantity of heat were exclusively expended in external work, it would be easy to determine, by the first law, the volume of the steam formed; for we should have $r=Apu$, and since r, A, and p are known, we might determine from this equation the volume u of the space K K′, (Fig. 10,) which is free in the cylinder under the piston, while one kilogram of water at $t°$ is converted into steam at $t°$. But the matter here is not so simple.

1. Temperature. (Cels.) t	2. Absolute temperature. $T = a + t$, $a = 273$	3. Pressure on 1 square metre in kilograms. p	4. Difference of pressure for 1° C. ϕ	5. Total heat according to Regnault. Q	6. Heat of evaporation according to Clausius. r	7. Volume by which 1 kilogram of water is expanded in being transformed into saturated vapor. u	8. Volume of 1 kilogram of saturated vapor in cubic metres. $v = u + 1$	9. Density of vapor, (weight of 1 litre of vapor in kilograms.) γ	10. Quantity of heat, which through the formation of vapor is transformed into work. $A p u$	11. Total heat contained in the vapor. $J = Q - A p u$	12. Internal latent heat of vapor. $\rho = r - A p u$
0	273	62. 5	....	606. 5	607. 00	207. 364	207. 365	0. 0000048	30. 59	576. 74	576. 74
5	278	88. 8	6. 4	608. 02	603. 46	148. 311	148. 312	67	31. 14	576. 50	571. 94
10	283	124. 6	8. 5	609. 55	599. 92	107. 786	107. 787	93	31. 68	577. 65	568. 02
15	288	172. 7	11. 2	611. 07	596. 38	79. 116	79. 117	126	32. 22	578. 77	564. 08
20	293	236. 5	14. 7	612. 60	592. 84	58. 703	58. 704	170	32. 74	579. 69	559. 93
25	298	320. 2	17. 5	614. 12	589. 30	44. 027	44. 028	227	33. 25	580. 90	556. 08
30	303	428. 9	24. 8	615. 65	585. 76	33. 369	33. 370	300	33. 76	581. 99	552. 10
35	308	568. 7	31. 7	617. 17	582. 22	25. 541	25. 542	391	34. 26	583. 06	548. 11
40	313	746. 5	40. 2	618. 70	578. 68	19. 735	19. 736	507	34. 75	584. 11	544. 09
45	318	970. 6	50. 4	620. 22	575. 14	15. 389	15. 390	650	35. 23	585. 16	540. 08
50	323	1250. 5	62. 6	621. 75	571. 60	12. 105	12. 106	826	35. 71	586. 22	536. 07
55	328	1597. 2	78. 2	623. 27	568. 06	9. 6031	9. 6041	1041	36. 18	587. 26	532. 05
60	333	2032. 3	94. 4	624. 80	564. 52	7. 6778	7. 6788	1302	36. 64	588. 30	528. 02
65	338	2541. 7	113. 7	626. 32	560. 98	6. 1866	6. 1876	1616	37. 09	589. 34	524. 00
70	343	3169. 2	138. 1	627. 85	557. 44	5. 0219	5. 0229	1991	37. 54	590. 39	519. 98
75	348	3922. 7	165. 2	629. 37	553. 90	4. 1049	4. 1059	2435	37. 98	591. 44	515. 97
80	353	4821. 7	196. 3	630. 90	550. 36	3. 3778	3. 3788	2960	38. 41	592. 50	511. 96
85	358	5887. 7	232. 2	632. 42	546. 82	2. 7971	2. 7981	3574	38. 84	593. 56	507. 96
90	363	7144. 0	272. 9	633. 95	543. 28	2. 3303	2. 3313	4289	39. 26	594. 64	503. 97
95	368	6816. 8	318. 9	635. 47	539. 74	1. 9526	1. 9536	5119	39. 68	595. 74	500. 01
100	373	10333. 0	370. 7	637. 00	536. 20	1. 6449	1. 6459	6075	40. 09	596. 83	496. 03
105	378	12323. 6	428. 8	638. 52	532. 66	1. 3932	1 3942	7172	40. 50	597. 91	492. 05
110	383	14621. 0	493. 5	640. 05	529. 12	1. 1858	1. 1868	8426	40. 90	599. 03	488. 10
115	388	17256. 0	565. 4	641. 57	525. 58	1. 0143	1. 0153	9849	41. 29	600. 14	484. 15
120	393	20275. 5	645. 1	643. 10	522. 04	0. 8710	0. 8720	11468	41. 68	601. 26	480. 20
125	398	23709. 8	732. 8	644. 62	518. 50	0. 7522	0. 7532	13277	42. 06	602. 39	476. 27
130	403	27603. 7	829. 1	646. 15	514. 96	0. 6519	0. 6529	15316	42. 45	603. 53	472. 34
135	408	32001. 3	934. 5	647. 67	511. 42	0. 5673	0. 7583	17596	42. 82	604. 68	467. 43
140	413	36949. 0	1049. 4	649. 20	507. 88	0. 4956	0. 4966	20137	43. 19	605. 84	464. 52
145	418	42495. 0	1174. 1	650. 72	504. 34	0. 4346	0. 4356	22957	43. 56	607. 00	460. 62
150	423	48690. 4	1309. 3	652. 25	500. 80	0. 3824	0. 3834	26082	43. 92	608. 16	456. 71
155	428	55588. 1	1455. 3	653. 77	497. 26	0. 3377	0. 3387	29525	44. 28	609. 35	452. 84
160	433	63243. 4	1612. 5	655. 30	493. 72	0. 2992	0. 3002	33311	44. 63	610. 53	448. 95
165	438	71712. 7	1781. 1	656. 82	490. 18	0. 2659	0. 2669	37467	44. 98	611. 71	445. 07
170	443	80054. 7	1961. 7	658. 35	486. 64	0. 2371	0. 2381	42000	45. 33	612. 92	441. 21
175	448	91330. 2	2154. 6	659. 87	483. 10	0. 2120	0. 2130	46949	45. 67	614. 34	437. 35
180	453	102601. 0	2360. 0	661. 40	479. 56	0. 1901	0. 1911	52328	46. 01	615. 34	433. 50
185	458	114930. 0	2578. 2	662. 92	476. 02	0. 1710	0. 1720	58140	46. 34	616. 54	429. 64
190	463	128383. 0	2809. 4	664. 45	472. 48	0. 1541	0. 1551	64740	46. 68	617. 79	425. 82
195	468	143025. 0	3054. 0	665. 97	468. 94	0. 1393	0. 1403	71276	47. 00	619. 01	421. 98
200	473	158923. 0	....	667. 50	465. 40	0. 1262	0. 1272	78616	47. 32	620. 26	418. 16

The quantity of heat r, which must be supplied to the unit weight of water at $t°$, in order to convert it into saturated vapor at $t°$, is known, indeed, by Regnault's experiments, but this quantity of heat divides into two parts; one part Apu serves to execute the external work pu; it is the other part ρ which is expended in overcoming the cohesion of the particles of water, and therefore in the performance of an internal work. Whence $r=\rho+Apu$. Neither ρ, nor Apu, nor the proportion of these two magnitudes is directly given; in order to determine them, we must first seek in some way to eliminate ρ, as it were, that is to say, we must propose some operation with the vapor by which a definite *external* work is performed, while the *internal* work performed shall, at the end of the operation, be nothing. A process of this sort is denoted by the name of a *circle-process*, (*Kreisprocess.*)

Fig. 11.



Let us suppose the volume w of the unit weight of water at $t°$, to be represented by the abscissa O A, (Fig. 11,) the pressure p, which is exerted thereon, by the ordinate A a. Let heat now be conveyed to the water in such wise that the vapor which is formed may maintain the constant temperature t. In virtue of this the pressure p also remains constant. The supply of heat is to be continued until all the water is converted into vapor. The volume w will now have been changed into O B$=v$, and will thus be increased by A B$=u$; and since the pressure p has in the meantime remained unchanged, the external work thus performed and represented by the rectangle A a b B is equal to pu. The quantity of heat supplied during this formation of vapor is r.

To this vapor we now allow, without supplying or withdrawing heat, a further small expansion from O B to O C, till the temperature be sunk 1° and the corresponding tension by ϕ. The work d thereby performed is represented by the quadrangle B C c b; and we will denote by q the corresponding heat which is disengaged from the vapor. In the fourth column of the table here given will be found the amount of diminution of tension ϕ, when the vapor, which is saturated for any one of the temperatures given in the first column of that table, is cooled 1°. The numbers of the table ranged under ϕ are found in the following manner:

If we subtract any of the values of p contained in the third column from the following one, we shall learn how much the tension of the saturated vapor is increased by an elevation of temperature of 5°. How much it is diminished by a lowering of temperature of 5°, we learn by subtracting from the same value of p the preceding one. If we now take the mean of these two differences, and of this mean the fifth part, we shall learn (without sensible error) how much the tension of the vapor of water is changed by an elevation or lowering of temperature by 1°. Thus, for example, for 150° C. the first difference is 6897.7; the second difference, 6195.4; the mean of the two is 6546.5; and the fifth part thereof, 1309.3, the number which stands under ϕ in the horizontal row of 150° C.

Let the vapor, which now has the temperature $t-1$ and the tension $p'=p-\phi$, be compressed by the volume u, (C D, Fig. 11,) while the heat is continuously withdrawn from it in such manner that the temperature shall always remain $t-1$ and the tension $p-\phi$.

The quantity of heat r' becoming free during this compression, and withdrawn from the vapor, consists of two parts, namely: of the quantity of heat $Ap'u$, which corresponds to the labor $p'u$ expended for the compression, and represented by the rectangle C D d c, and the quantity of heat ρ which becomes free by the condensation of a corresponding quantity of vapor.

Let the compression now be finally continued from O D to O A, without the addition or abstraction of heat; the temperature will thereby be raised to $t°$, the

pressure to p, and the vapor will again be fully restored to its original state, (water of $t°$.) In this last part of the operation the work d, represented by the rectangle $D\,d\,a\,A$, is expended, and thereby the quantity of heat q is again supplied to the body under experiment, a quantity which it had lost during the expansion from O B to O C.

While the water has been thus fully restored to its original state, the work $pu+d$ will, during the operation cited, have been performed through the expenditure of the quantities of heat r and q, and thereupon the quantity of heat $r'+q$ have been gained by the expenditure of the work $p'u+d$. The sum of the work gained is thus,

$$pu+d-p'u-d=\phi\, u,$$

a work which is represented by the shaded parallelogram $a\ b\ c\ d$, (Fig. 11.) The heat expended in producing this work is,

$$r+q-r'-q=r-r'.$$

But the quantity of heat requisite for the performance of the work $\phi\ u$ is $A\ \phi\ u$; we have then the equation

$$A\,\phi\, u=r-r'.$$

Now, in this equation the values $A\ \phi$ and r are already known; only r', therefore, is wanting to enable us to determine that of u. And as the rigorous solution of this problem is not possible without the aid of the higher analysis, we must here content ourselves with an elementary process of approximation.

The quantities of heat Apu and $Ap'u$ stand evidently in proportion to the tensions p and p'; and to these we may assign as proportional, since the question regards only slight differences of temperature, the density of the vapor of water at $t°$ and at $(t-1)°$. But to these densities are also proportional the quantities of water which, at the temperature $t°$, are evaporated during the expansion through the volume u, and at the temperature $(t-1)°$ are condensed during the compression through the volume u. Whence, therefore, we have $\rho:\rho'=p:p'$, and

$$\rho+A\,p\,u:\rho'+A\,p'u=p:p', \text{ or } r:r'=p:p'.$$

But since, within such narrow limits of temperature, the saturated vapor may be assumed as following the law of Mariotte Gay-Lussac; therefore

$$p:p'=1+\alpha\, t:1+\alpha\,(t-1)$$

consequently, also,

$$r:r'=1+\alpha\, t:1+\alpha\,(t-1)$$

$$r'=r\frac{1+\alpha(t-1)}{1+\alpha t}$$

$$r-r'=r\left\{1-\frac{1+\alpha\,(t-1)}{1+\alpha\, t}\right\}$$

$$r-r'=\frac{r\,\alpha}{1+\alpha\, t}$$

or, if we divide numerators and denominators by α, and take $\frac{1}{\alpha}=a$,

$$r-r'=\frac{r}{a+t}=\frac{r}{T},$$

if T denote the absolute temperature* which corresponds to $t°$ C. Thus we have

*Let p be the elastic force of a confined mass of air at 0°; then, according to Mariotte Gay-Lussac's law, this elasticity at $t°$ C. is equal to $p\,(1+0.00365\,t)$; the elastic force of the enclosed mass of air is thus null, if $1+0.00365\,t=0$; that is to say, if $t=-273°$ C. At this temperature, which is 273° below the freezing point of water, the gases lose their power of expansion; and it is this point which we indicate as the *absolute zero-point*. It is the temperature counted from this point onward, according to the Celsius degrees, $T=273+t$, (if t be the temperature counted onward from the freezing point of water,) which is denoted as absolute temperature. In the second vertical series of our foregoing table are given the absolute temperatures which correspond to the temperatures of the first column measured by the thermometer of Celsius.

$$\left.\begin{aligned} &A\varphi u=\frac{r}{T} \\ \text{and} \\ &u=\frac{r}{AT\phi} \\ \text{or} \\ &u=\frac{424 \cdot r}{T \cdot \varphi} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad \text{(II)}$$

if for $\frac{1}{A}$ we place its numerical value 424. From this equation, which is regarded as the *second general equation of the mechanical theory of heat*, the appropriate value of u at every given temperature admits of being calculated, as r, T, and ϕ are known magnitudes. Thus, for example, for $t=120°$ we have

$$u=\frac{424 \cdot 522.04}{393 \cdot 645.1}=0.8731,$$

and for $t=150°$,

$$u=\frac{424 \cdot 500.8}{423 \cdot 1309.3}=0.3834.$$

Our table contains in the seventh column the value of u for the temperatures given in the first vertical series.

To these values of u we have only to add 0.001, (the volume of one kilogram of water expressed in cubic metres,) in order to obtain the volume v, which one kilogram of saturated vapor of the corresponding temperature occupies. The numerical values of v are presented in the eighth column of our table. From this we see, for example, that one kilogram of saturated vapor of 100°, of 130°, of 160°, &c., occupies the volume of 1.6459, of 0.6529, of 0.3002, &c., cubic metres.

If the saturated vapors of water followed Mariotte Gay-Lussac's law, then the product $\frac{pv}{1+at}$ must be a constant magnitude. But this product is

46376 for $t=100°$
37832 for $t=130°$
32374 for $t=160°$;

thus for increasing temperatures it becomes continually smaller. From the application of the mechanical theory of heat to saturated vapors it results, therefore, as Clausius first showed, that these do not follow Lussac's law; that rather the elasticity of saturated vapor increases less rapidly with increasing temperature than the density thereof.

Since the quotient $\frac{1}{v}$ indicates the weight of one cubic metre of saturated vapor, $\frac{1}{1000\,v}$ is the weight of one cubic decimetre, consequently, also, the *specific weight* or *density* of the same. The numerical values of the density of saturated vapor are given under γ in the 9th column of our table.

If we multiply the enlargement of volume u, which ensues from the transformation of one kilogram of water at $t°$ into saturated vapor of $t°$, into the corresponding pressure p, we obtain the external work performed through this operation, while the quantity of heat spent in the performance of this work is Apu. The numerical values of Apu, which stand in the 10th column of our table, are, however, not calculated in the above-cited manner, but according to the empirical equation proposed by Zeuner: $Apu=30.456 \cdot \log \cdot \frac{T}{100}$, whose results so nearly accord with those computed after the above theory that we may

well adopt this equation as the true expression of the relations between p, u, and t. Again, the values of u, as stated in the 7th column, are not those calculated in the way above given, but those very nearly the same, which are obtained by a division of the values of Apu, given in column 10, by the corresponding values of Ap.

Let us now briefly consider the signification of the magnitudes represented in the table.

Q, as already said, is the total quantity of heat which is expended in order first to heat one kilogram of water at 0° to $t°$, and then to convert the water of $t°$, under the corresponding pressure p, into saturated vapor of $t°$.

A part of this quantity Q, namely, Apu, is spent in external work; it is, therefore, no longer contained in the saturated vapor at $t°$; the total quantity of heat contained in the vapor (excepting that already in the water at 0°) is only $J=Q-A\,p\,u$. The values of J are represented in the 11th column of our table.

In order to transform water at $t°$ into saturated vapor at $t°$, the quantity of heat r is necessary, whose values are exhibited in the 6th vertical series of the table. It is this magnitude r which is usually designated as *latent heat*; an incorrect expression, however, if we mean thereby to indicate the quantity of heat employed in *abolishing the cohesion of the particles of water*, and hence spent in an external work, for a part of the quantity r, namely, Apu, is consumed by that external work. Only the remainder, $\rho=r-Apu$, can be regarded as the internal latent heat of vapor, while the magnitude r might, according to Clausius, be designated as evaporation-heat.

It is evident that for a correct calculation of the effects of steam-engines the values of v must be taken into account as they are set forth in our table, and not hose reckoned after M. Gay-Lussac's law. It is to be observed, however, tn a comparison of the values of V and v, given in two preceding pages, that in the last the volume of one gram of vapor is expressed in cubic centimetres, iwhile in the first it is stated in cubic metres.

From a consideration of the numbers grouped together in the table it will be seen that of the quantity of heat conveyed to the water in the boiler only a very small part is expended in mechanical work; for the quantity Apu employed in such work is but an inconsiderable fraction even of the evaporation-heat r, about $\frac{1}{13}$ for 100°, and $\frac{1}{11}$ for 160°. The internal latent vapor-heat ρ abides with the vapor at its exit from the machine, and hence can do no work. This quantity of heat ρ can only be in part regained.

This circumstance occasioned the constructing of power machines, in which the elasticity of heated air might operate instead of steam. Such machines, constructed particularly after Ericsson's designs, and known by the name of caloric engines, have been repeatedly introduced into practice with high expectations, but have been as often abandoned because their performance fell far short of that of the steam-engine.

VIII.—ACTION OF SATURATED STEAM DURING EXPANSION.

The results thus far obtained enable us to form a correct idea of the action of steam in our expansion steam-engines. As we cannot, however, here develop the equations necessary for the general solution of this problem, we must content ourselves with the consideration of special cases.

If, under the piston of a steam-cylinder, there be just one kilogram of saturated steam of 160° C., we find for this steam by our table,

$v=0.3002$ cubic metre.
$p=63243.4$ kilograms.
$J=610.53$ units of heat.

Let the steam be now supposed slowly to expand, and the pressure on the piston to be, at each moment, equal to the corresponding tension of the steam. During this expansion both the temperature and elasticity of the steam is lowered.

Suppose the steam to expand till its temperature has fallen 5°, and hence in the case under consideration from 160° to 155°. We will inquire now how much heat must be supplied to this expanding steam, if, during the expansion in question, no condensation take place and the quantity of steam is to remain unaltered. By our table we have for 155°,

$$v'=0.3387 \text{ cubic metre.}$$
$$p'=55588.1 \text{ kilograms.}$$
$$J'=609.35 \text{ units of heat.}$$

The volume of the steam has therefore increased by $V=v'-v=0.0385$ of a cubic metre. The work done during this expansion we know at least approximately, $L=V\cdot\frac{p+p'}{2}$ whence, in our special case, we put

$$L=0.0385\cdot 59415.7=2287.5 \text{ metre-kilograms;}$$

the quantity of heat requisite for this work is,

$$A\,L=\frac{L}{424}=\frac{2287.5}{424}=5.39 \text{ units of heat.}$$

At the beginning of the expansion the total heat contained in the steam, $J=610.53$, at the termination of the expansion, $J'=609.35$; thus we see that during the expansion, $J-J'$, equal in units of heat to 1.18, has disappeared from the steam. But this quantity of heat is not sufficient to execute the work amounting to 2287.5 metre-kilograms; so that $5.39-1.18=4.21$ units of heat must be added from without, if the steam is to expand in the manner above stated, without diminution of the quantity of steam.

If we repeat the same process for the temperature standing in the beginning at 120°, (instead of 160°, as in the preceding case,) we find,

$$V=v'-v=0.1433.$$
$$p+p'=18767.2.$$
$$L=2689.3.$$
$$A\,L=6.34 \text{ units of heat.}$$
$$J-J'=1.12 \text{ units of heat.}$$

In this last case, therefore, an addition of $6.34-1.12=5.22$ units of heat is needed. Now, if the numerical values just calculated, make no pretension to exactness, they still serve to show that a considerable addition of heat is necessary if the steam is to expand in the way specified, *without the occurrence of partial condensation.*

But since, in our expansion steam-engines, no further addition of heat ensues after the shutting off of the supply of steam, it is clear that in consequence of the expansion *a partial condensation of steam must follow.* The last part, therefore, of the proposition announced by Pambour, "Steam, while expanding without heat being supplied, remains saturated, and no vapor is thereby precipitated," is inadmissible; much rather would it be proper thus to modify the proposition, "While steam is expanding without a supply of heat, it remains, indeed, saturated, *but thereby is a proportional quantity* of vapor precipitated." Hence, at the end of the expansion the quantity of steam is less than at its commencement.

It is through the condensation of steam that the heat must be furnished, which is in deficiency, for the performance of the work of expansion.

This important discovery, respecting the action of steam during its expansion, was made almost simultaneously by Clausius and Rankine. It is clear that the *theory of steam-engines* must, from this fact, undergo an essential modification.

That the expansion of steam is attended by partial condensation, admits of being likewise experimentally demonstrated. Into a glass balloon, (Fig. 12,)

which is wrapped around with wire and provided with a brass appendage which contains a duct, closed at will by a cock, we introduce a little water, so that the glass may be moistened within by a few drops. The balloon is then screwed to a compressing pump, and so much air is pumped in that the tension in the interior of the balloon shall amount to about three atmospheres. If the cock be now closed, and the balloon be unscrewed and laid in some warm place, whether in the vicinity of a stove or in the sunshine, the vapors in the interior will, after a while, have acquired the elasticity corresponding to the temperature, and appear perfectly transparent. If the cock be now opened, air and vapor will rapidly escape from the balloon, and the latter will be filled with a thick mist.

Fig. 12.

In a somewhat altered form, the experiment admits of being executed as follows: Let the bell of an air-pump be sprinkled on the inside with a little water, and after being placed on the plate of the pump, be left some time in a rather warm chamber. As soon now as we begin to discharge the air, a white mist will be formed within the bell.

A corresponding experiment has been instituted by Hirn on a large scale. A straight copper cylinder, two metres long and 15 centimetres in diameter, was closed at both ends by flat plates, in the middle of which were openings two centimetres wide and closed by plates of glass cemented therein. This cylinder was on one side placed in connection with a steam-boiler, while on the other it bore a discharge tube which was furnished with a wide cock. Into the cylinder was now introduced steam of a high tension, while the escape-cock was only partially opened, so that all the air might find an issue. The highly condensed vapor, (five atmospheres, for example,) which in this way fills the cylinder, is now perfectly transparent, so that all objects are plainly visible through the glass plates mentioned above. If the influx of steam from the boiler be afterwards wholly shut off, and the escape-cock be suddenly and fully opened, so that the steam promptly expands to a tension of one atmosphere, a mist of such density is formed in the cylinder that its contents appear completely opaque.

IX.—THE MELTING OF ICE.

After having applied the principles of the mechanical theory of heat to the formation of steam, we will proceed to consider them in relation to the phenomena of melting, and shall here treat exclusively of the melting of ice.

Let us suppose one kilogram of ice at 0° C. to be contained in a vessel, under the pressure of one atmosphere. If heat be communicated to this ice, *while the pressure remains unaltered*, the ice passes gradually into water, but the temperature continues at 0° until the liquefaction is wholly completed. From this moment first begins the elevation of temperature, if the supply of heat is maintained.

The quantity of heat which is necessary thus, under the pressure of one atmosphere, to convert one kilogram of ice at 0° into water at 0°, taking the mean of the best experiments, is, $r=79.035$ units of heat. This quantity is usually called, as in the case of steam, the *latent heat*.

The phenomenon of melting is wholly analogous to that of evaporation. A part of the heat supplied to the ice is expended in *overcoming the cohesion*, the other part in *external work*, as, during the melting, a change of volume takes place.

As in the formation of steam, if it takes place under the conditions set forth in § 7 the temperature at which the transformation into vapor occurs is a function of the pressure exerted on the piston, so that we might expect that the temperature of the melting ice depends also on the pressure under which it stands; that the temperature of fusion also varies with the pressure.

From the analogy between vaporization and fusion, we are authorized to apply to the phenomenon of melting the equations developed in section VII, and therefore the second leading equation of the mechanical theory of heat $u=\frac{r}{A \cdot T \cdot \phi}$. But while, in the formation of steam, the magnitude ϕ was given through the experiment, it is here wholly unknown; on the other hand, we know the quantities r, A, T, and u, and hence have

$$\phi=\frac{r}{A \cdot T \cdot u} \qquad \qquad (111)$$

As we have above seen, $r=79.035$. The absolute temperature at which, under the pressure of the atmosphere, the melting of ice takes place, is $T=273°$. We know, moreover, that $A=\frac{1}{424}$. For the computation of ϕ there is wanting, therefore, only the value of u. In the melting of ice, we know a diminution of volume takes place. The volume of one kilogram of water at 0° is $v=0.001$ cubic metre. The volume of one kilogram of ice at 0°, taking the mean of different computations, is $w=0.00109$; hence

$$u=v-w=-0.00009,$$

and therefore negative. If we place now for r, A, T, and u, in equation, (111,) the numerical values cited, the result is

$$\phi=-\frac{79.035 \cdot 424}{273 \cdot 0.00009}.$$

Should the difference of pressure ϕ, which corresponds to a lowering of temperature of 1°, be expressed, not in kilograms, but in atmospheres, we shall have to divide by 10333, and we then obtain

$$\phi=-\frac{79.035 \cdot 424}{10333 \cdot 0.00009 \cdot 273}=132 \text{ atmospheres};$$

that is to say, an augmentation of pressure from 1 to 132 atmospheres would correspond to a lowering of the melting point by 1° C.; an augmentation of the pressure by one atmosphere will therefore be followed by a lowering of the melting temperature of ice equal to $\frac{1}{132}$, or 0.0075° C.

That the temperature at which ice melts varies with the pressure, and that thus *an elevation of the pressure corresponds to a lowering of the freezing point*, was first theoretically demonstrated by James Thomson, (Proceedings of the Royal Society of Edinburgh,) and then by Clausius, (Pogg. Annal., LXXXI,) and was experimentally verified by William Thomson, (Pogg. Annal., LXXXI.) The latter availed himself, for this experiment, of a thermometer in which ether was employed instead of quicksilver as the thermometric fluid. The reservoir of this thermometer was three and a half inches long and three-eighths inch wide. On the tube, six and a half inches long, was a scale of five and a half inches length, divided into 220 equal parts. The extent of this scale corresponded to a difference of temperature of about 3° F., so that a division represented on an average $\frac{1}{71}$ of a degree of F. The thermometer was so regulated that it showed the temperature between 31° and 34° F. In order that the reservoir might not be compressed when submitted to a strong pressure, it was hermetically inclosed

in a wider glass tube; this outer tube contained enough quicksilver for the reservoir of the ether thermometer to be wholly surrounded by it.

This thermometer was now plunged, together with a cylindrical tube filled with air, into Oersted's compressing apparatus, which was filled partly with water, partly with pieces of pure ice. By means of a ring of lead, care was taken to keep the water of the compressing vessel free from ice at that part of the thermometer on which the readings were to be made. A pressure of 8.1, and again of 16.8 atmospheres, produced a sinking of the thermometer by $7\frac{1}{2}$ and $16\frac{1}{2}$ of the divisions of the scale, and thus by $\frac{7.5}{71}=0.106°$ F., and $\frac{16.5}{71}=0.232°$ F.; which very nearly coincides with the theoretically calculated depression of 0.109° and 0.227° F.

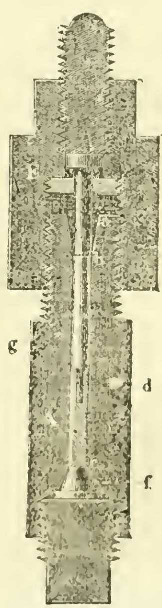
From the above developments and observations it might be expected that water under very high pressure must remain fluid at relatively low temperatures. That this, indeed, is the case, is confirmed by the experiments long since conducted by Williams in Quebec, in order to measure the force with which freezing water expands. He exposed to intense cold thick iron bomb-shells, filled with water and closed by means of an iron plug firmly driven in. At a very low temperature the stopper was either driven out and then an icicle was projected from the opening, (Fig. 13,) or the bomb was burst, and in that case a sheet of ice protruded from the fissure, (Fig. 14.) The form of these extruded pieces of ice indicated conclusively that the water at a very low temperature still remained fluid, and was first converted into ice at the moment when it gained additional space.

Fig. 13.

Fig. 14.

In fine, Mousson has shown (Pogg. Annal., CV) that at a very low temperature ice may be rendered fluid by great pressure. The apparatus of which he availed himself for this is represented in section in Fig. 15, and on a smaller scale in side elevation in Fig. 16. Through the axis of a massive prism A of the best steel, four-cornered below and furnished above with the worm of a screw, a cylindrical cavity, 7.12 millimetres wide, is drilled, which, in its upper part, widens from b to a, in a slightly conical form, so that the mouth at a has a diameter of 8.61 millimetres. From above is driven into the cylindrical cavity a piece of pure copper g, somewhat conical at first, and fitting into the cavity $a\ b$ so as to form above a perfect closure of the same. To the copper cylinder g is affixed a steel prolongation D, of like diameter with the cavity $b\ c$, and which, by application of the female screw E, can be pressed downwards so as to drive the copper cylinder g further into the cavity $b\ c$. Underneath the cylindrical cavity $b\ c$ is also a conical but rapidly widening cavity, into which fits the copper cone f, which, by means of the steel screw C, can be firmly pressed into its cavity.

Fig. 15.



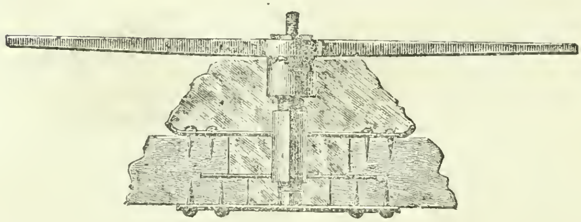
In order to perform the experiment, the screw C and the copper cone f were first removed, the whole apparatus was inverted, so that E was below, A above, and the free part of the cavity $b\ c$, above g, was filled with water that had been boiled; the copper index d was now lowered into this water. With the position unchanged, while d thus stood upon g, the whole apparatus was exposed to a low tempera-

ture, the water froze, and thereby the copper index was fixed at the place which it occupied. The nipple of ice formed by the freezing of the water in the conic space at c was removed, the copper cone f introduced, and by means of the screw C driven in as strongly as possible. The whole apparatus was now again reversed, so that E was above and C below.

Fig. 16.

After the apparatus, in this last position, was firmly secured in a strong cross-piece between two bars, (Fig. 17,) and surrounded with the freezing mixture, the index d being thus plunged in the ice deep under g, the female screw or nut E was, by means of a lever six decimetres long, gradually driven around, and thereby g more and more pressed downward. If the ice remained firm under the compression, there must, on the opening of the screw C, situated below, appear at the copper cone f first a cylinder of ice and then the index d; but if water has been produced by the pressure, the index d must descend to c, at the lower end of the cavity, and hence, on the withdrawal of f, first the index and next in order the massive ice cylinder respectively make their appearance.

Fig. 17.



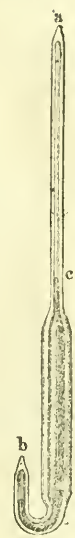
In order to prevent the heating of the apparatus by mechanical work the depression of g was very slowly conducted, the female screw E being turned only every five minutes to the extent of 45°, and the operation being thus protracted through the space of some four hours. When, after these processes, the lower terminal screw was opened, still under a very low temperature, the copper cone f immediately protruded and ice instantly formed on its sides. Directly behind the cone f followed the index d, and after this a thick cylinder of ice, which must have been formed at the moment of the opening.

Thus was the proof afforded that, *by a sufficiently strong pressure, ice is converted into water at* $=18°$ C. The pressure to which the ice was subjected in this experiment is estimated by Mousson at some 13,000 atmospheres. This lowering of the melting point of ice through pressure plays an important part in the explanation of glacier-phenomena, and on that account will be again the subject of consideration in the section of cosmical physics.

The value of ϕ, (in equation 111) is, for water, a negative one, because ice, in melting, contracts. For such substances, however, as are attended in melting with an augmentation of volume, ϕ is positive, and for these therefore *the melting*

point must, through increased pressure, be heightened. The correctness of this consequence has been experimentally proved by Bunsen, (Pogg. Annal., LXXXI, 1850.) and by Hopkins, (Dingler's Polyt. Journal, CXXXIV.) Bunsen conducted the experiment in the following manner: A very thick-walled glass tube about a foot long, and having a bore of the size of a straw, was drawn out at one end into a fine capillary tube from 15 to 20 inches in length, which was made of as accurate calibre as possible. The lower end of this glass tube was also drawn out to a somewhat wider tube, one and a half inch long and curved, as is shown in Fig. 18.

Fig. 18.



By atmospheric pressure the whole apparatus was now filled with quicksilver, and the longer capillary tube was then soldered at *a*. After cooling, a small quantity of quicksilver was driven out at *b* by gentle heat, and in place of it, while the cooling was renewed, a small quantity of the substance to be tested was imbibed in a state of fusion. The apparatus was now soldered also at *b*, the longer capillary tube was then opened at *a*, and the whole apparatus heated one or two degrees above the melting point of the substance contained therein, through which process a part of the quicksilver is expelled from the open point at *a*. Finally, after renewed cooling, the range of the quicksilver in the capillary tube at *c*, together with the range of the thermometer and barometer, was noted; the point at *a* was then once more soldered, and thus a column of air of ascertained length was included.

Two such instruments of precisely similar form and contents, one of which was soldered at *a*, while the other remained open, were now, together with a sensitive thermometer, fastened on a small board in such manner that the two little tubes filled with the substance to be tested might stand close to the bulb of the thermometer. If this apparatus be immersed in water whose temperature is a few degrees above the melting point of the substance, to such a depth that only the tube *b* shall be submerged, it will be seen that, by gradual cooling of the water, molecular rigidity will ensue simultaneously in both tubes. But were the apparatus sunk deeper in the warm water, there would follow, through the expansion of the quicksilver in the closed instrument, a pressure which can be readily measured by the compression of the air in the capillary tube *c b*, and which may be augmented or diminished at will by depressing the instrument in the warm fluid or partially withdrawing it therefrom. The pressure in the open instrument, on the other hand, remains unchanged during the whole experiment. The difference of temperature at which the substance grows rigid in the closed instrument sooner than in the open one gives the elevation of the melting point for the observed pressure.

An experiment made with spermaceti gave the following result:

Pressure.	Point of rigidity.
1 atmosphere	47.7° C.
96 atmospheres	49.7°
156 atmospheres	50.9°

The same experiment repeated with paraffine gave:

Pressure.	Point of rigidity.
1 atmosphere	46.3° C
85 atmospheres	48.9°
100 atmospheres	49.9°

By another method, Hopkins obtained the following results:

Melting temperature.

Pressure.	Spermaceti.	Wax.	Sulphur.	Stearine.
1	51° C.	64.5° C.	107.0° C.	72.5° C.
519	60°	74.5°	135.2°	73.6°
792	80.2°	80.2°	140.5°	79.2°

X. SPECIFIC HEAT IN THE ACCEPTATION OF THE MECHANICAL THEORY OF HEAT.

By the specific heat of a substance is understood, we know, the number which specifies how many units of heat (*calories*) must be added to the unit of weight of that substance in order to produce an elevation of temperature from 0° to 1° C.

According to a law propounded by Dulong and Petit, the product obtained when the specific heat of a solid element is multiplied by its atomic weight should be a constant number; which is, indeed, nearly the case, as the following brief table will show:

	Atomic weight.	Specific heat.	$p \cdot s$.
Silver	108.0	0.0570	6.16
Alumina	27.4	0.2143	5.87
Copper	63.4	0.0949	6.02
Iron	56.0	0.1138	6.37
Lithium	7.0	0.9408	6.59
Natrium	23.0	0.2934	6.75
Lead	207.0	0.0314	6.50
Sulphur	32.0	0.1776	5.68
Zinc	65.2	0.0956	6.23

The Dulong-Petit law admits of being expressed in this wise: *Chemically equivalent quantities of solid elements require for like elevation of temperature quantities of heat of like amount.* Still another expression of the same law is the following: *The atoms of all simple substances have a like capacity for heat;* or, in fine, *the atomic heat of all simple substances is equal,* if we denote by atomic heat the product of the atomic weight into the specific heat.

In the mean, the atomic heat of solid elements has the product $p \cdot s = a$, or the value 6.4. From this value, however, the atomic heat of carbon deviates considerably, since we have for—

	p	s	$p \cdot s$.
Charcoal	12	0.241	2.89
Graphite	12	0.174	2.09
Diamond	12	0.147	1.76

The atomic heat of the different forms of carbon is somewhat more approximate to the mean value of the atomic heat of the rest of the elements, if, according to Regnault's proposition, we take the atomic weight of carbon not as equal to 12, but to 24.

If we indicate the atomic weight of a compound body by P, its specific heat by S, and by N the number of single atoms which are associated with one atom of the compound body, then, according to Garnier, we have very nearly $\frac{P \cdot S}{N} = a$, if a represent the mean atomic heat of the solid elements, and, therefore, the value 6.4. In effect there results, for example, for

	Chemical formula.	P	S	N	$\frac{PS}{N}$
Cinnabar	HgS	232.0	0.0517	2	6.0
Rock salt	NaA	58.5	0.219	2	6.4
Red copper	$\mathrm{\Theta}a_2\Theta$	142.8	0.111	3	5.3
Water	$H_2\Theta$	18.0	1.00	3	6.0
Specular iron, (*Eisenglanz*)	$Fe_2\Theta_3$	160.0	0.154	5	5.0

Now the temperature of a body depends, according to the mechanical theory of heat, entirely on the living force with which the atoms composing it move. Two bodies have a like temperature when the living force with which each atom in the one vibrates is equal to the living force of an atom in the other. For the temperature of two bodies to be raised in an equal degree it is necessary that the oscillatory work of the atoms in both should undergo an equal augmentation.

From this it might well be expected that like quantities of heat will be needed to produce a like elevation of temperature in two masses of different substance of which one contains just as many atoms as the other; or, in other words, it would be expected that the magnitude, which we have above indicated as atomic heat, should for all elements be alike; that, hence, the Dulong-Petit law should not only be approximately, but rigorously, correct, that for chemically compounded substances the quotient which we obtain when we divide the atomic heat of the combination by the number of single atoms which are associated with one atom of the composition, being the value $\frac{PS}{N}$, must under all circumstances be perfectly equal to the atomic heat of the simple substance. This, however, experiment does not verify. The numbers of the last column of the above table, in part, deviate considerably from 6.4, and thus the quotient $\frac{PS}{N}$ is not equal for all combinations, as we have also seen above.

The contradiction in which experiment and the mechanical theory of heat seem here involved entirely vanishes, however, when it is considered that the quantity of heat which must be supplied to a body in order to raise its temperature is by no means wholly employed in exalting the living force of its molecular vibrations, but that a considerable part of the heat, which we designate as specific heat, is consumed in the performance of internal and external work.

Let us indicate the specific heat of a simple substance by s; then is,

$$s = k + i + e \quad . \quad . \quad . \quad . \quad (1),$$

if by k we denote the augmentation of the vibratory work which the unit weight (*Gewichtseinheit*) of the substance in question undergoes from an elevation of temperature of 1°, while i and e denote the heat equivalent of the internal and external work simultaneously executed. If we designate the atomic weight of the substance by p, then, according to the principles of the mechanical theory, the product kp must, of course, be the same for all simple substances; but it by no means follows that sp also is a constant magnitude, since e and i are quantities which vary, not only from one substance to another, but for the same substance with the conditions of aggregation. We can realize the absolute validity

of the law of Dulong and Petit only when both quantities i and e are completely null. Only in special cases can the quantities e and i be small enough to admit of their being neglected. This circumstance, however, makes it possible to ascertain the value of the quantity k.

For solid and fluid bodies the expansion which corresponds to an elevation of temperature by 1° is so slight that we may overlook, without sensible error, the *external work* thereby executed; for this case, therefore, we have

$$s=k+i \quad . \quad . \quad . \quad . \quad (2).$$

On the other hand, it may be assumed that, at least with the permanent gases, the *internal work* is null; whence, for these we have

$$s=k+e \quad . \quad . \quad . \quad . \quad (3),$$

if by s the specific heat of these gases under *constant pressure* be indicated. For the case in which the gas is so confined as not to be capable of expanding from subsequent heating, e is also null; and we then have

$$s'=k \quad . \quad . \quad . \quad . \quad (4),$$

if by s' be indicated the specific heat of gases under *constant volume*.

According to the experiments of Regnault, the specific heat is, with constant volume, for oxygen gas, 0.1551; for hydrogen gas, 2.4153; for nitrogen gas, 0.1712; whence the atomic heat is for oxygen gas, $0.1551 \cdot 16=2.4816$; for hydrogen gas, $2.4153 \cdot 1=2.4153$; for nitrogen gas, $0.1712 \cdot 14=2.3968$. We will take, then, 2.4 for the approximate value of the atomic heat under constant volume, for the gases named.

This value, 2.4, we will now designate as *absolute atomic heat*. It would be the atomic heat for all elements, whether in a fluid, solid, or gaseous state, if all the heat supplied to them inured exclusively to the augmentation of the vibratory work, and none of it were employed for internal and external work.

The knowledge of the absolute atomic heat 2.4 enables us to ascertain what part of the specific heat s of a body inures to the elevation of temperature, and what part thereof becomes latent through the performance of internal or external labor. For solid elements the atomic heat is, according to equation (2),

$$sp=(k+i)p.$$

For the absolute atomic heat kp of all elements we have found the value 2.4; whence,

$$(s-i)p=2.4, \text{ and } s-i=\frac{2.4}{p}.$$

The quotient $\frac{2.4}{p}$, which we will call the *absolute specific heat*, or the *absolute heat-capacity*, is the same quantity which we designated above by k; we find it for each element if we employ its atomic weight p as a divisor for 2.4.

Thus, for example, we obtain for copper $k=\frac{2.4}{63.4}=0.0378$. Of the quantity of heat 0.0949, which must be supplied to one gram of copper in order to raise its temperature 1°, only 0.0378 units of heat are expended for the elevation of temperature, (increase of vibratory work;) the rest, $0.0949-0.0378=0.0571$ units of heat, are consumed for internal work, and hence are latent. In the same way we obtain for certain solid elements, which are exhibited together in the fol-

lowing table, the values of the specific heat s, of the absolute specific heat k, and of the heat expended for internal work i.

	s	k	i
Silver	0.0570	0.0222	0.0348
Alumina	0.2143	0.0875	0.1268
Copper	0.0949	0.0378	0.0571
Iron	0.1138	0.0430	0.0708
Lithium	0.9408	0.3428	0.5940
Natrium	0.2934	0.1043	0.1891
Lead	0.0314	0.0126	0.0188
Sulphur	0.1776	0.0756	0.1020
Zinc	0.0956	0.0372	0.0583

If we seek to ascertain in this way the value of k for carbon, we obtain, by taking the atomic weight 12 as a basis, $k=0.2$, a value which is greater than the value of s heretofore found for graphite and diamond. This circumstance speaks decisively to the effect that, agreeably to Regnault's proposition, we should double the atomic weight of carbon and assume it to be equal to 24; we then have, for the different forms of aggregation of carbon, the values of s, k, and i, exhibited in the following brief table:

	s	k	i
Charcoal	0.241	0.1	0.142
Graphite	0.174	0.1	0.074
Diamond	0.147	0.1	0.047

The inequality of the specific heat of different forms of aggregation of carbon thus becomes intelligible, from the consideration that at a like elevation of temperature the internal work performed is different, according as we are dealing with diamond, graphite, or charcoal.

In strictness, therefore, the law of Dulong and Petit is, in general, only valid for the *absolute* specific heat k, which, multiplied by the atomic weight of the element, gives the constant product $kp=2.4$. The variations which the specific heat of solid elements undergoes, when the temperature is raised, are likewise to be ascribed to a difference in the amount of internal work.

In reference to chemically compounded substances, we have, for ascertaining their *absolute capacity* of heat K, the equation

$$\frac{\mathrm{P\,K}}{\mathrm{N}}=2.4 \quad . \quad . \quad . \quad . \quad (5),$$

which is found from equation $\frac{\mathrm{P \cdot S}}{\mathrm{N}}=a$ if we put K in the place of the experimentally determined specific heat S, and the absolute specific heat of the element 2.4 in the place of a. From equation (5) results $\mathrm{K}=2.4\frac{\mathrm{N}}{\mathrm{P}}$. For water, for instance, we have $\mathrm{N}=3$, $\mathrm{P}=16+2=18$; hence $\mathrm{K}=2.4\frac{3}{18}=0.4$; thus the absolute specific heat of water in a solid, liquid, and gaseous form, is equal to 0.4. From these premises we obtain, for the quantity of heat i, which, by an elevation of temperature of 1° C., is expended in internal work,

for ice . . . . $i=0.5-0.4=0.1$
for liquid water . $i=1.0-0.4=0.6$.

THE THERMIC MOLECULAR MOTION.

From the equivalency of heat and labor it undoubtedly results that every development of heat by mechanical means must be regarded as the *transformation of a bodily motion into a molecular motion;* and, conversely, that every performance of work must be considered a *transformation of the molecular motion into a bodily motion.* This view constitutes the starting point of the mechanical theory of heat, of which the most essential principles, together with some of the most important consequences springing from them, have been discussed in the preceding paragraphs, without reference, however, to the conception which we must form of this molecular movement, whose results are the different phenomena of heat.

For the completion of the mechanical theory there is certainly needed an hypothesis respecting the nature of this molecular action, although many important questions may be and have been solved without one. In the mean time the construction of such an hypothesis has exercised the ingenuity of different physicists, especially of Clausius, Krönig, and Redtenbacher.

Krönig and Clausius (Pogg. Annal., XCIX and C) suppose that the minute molecules of gases and vapors, mere points in proportion to the intervals which separate them, move on with a constant velocity, in right lines, until they impinge against another molecule of the same nature, or against some object to them impenetrable. The pressure of gases against a solid surface is supposed to result from the fact that the molecules in great number continually impinge against the resisting surface and rebound from it. By an increase of temperature the velocity with which the molecules move is augmented; and, in fine, the temperature is assumed to be proportional to the square of that velocity.

In the case of solid bodies, the molecules oscillate about a permanent point of equilibrium; while in the case of fluids this point of equilibrium does not exist; but the molecules, notwithstanding their constant and manifold movements, are restrained to determined distances, and cannot, like the gases, move freely apart from one another.

While the savants just named seek the causes of the phenomena of heat in a movement of the atoms themselves of bodies, Redtenbacher considers the oscillations of the atoms of the ether enveloping the atoms of a body to be the source of those phenomena, as he has explained in his "Dynamiden system," (Manheim, 1857.)

A circumstance which speaks with much force in favor of the views of Krönig and Clausius is that through these views the difference between radiant and sensible heat admits of easy explanation. The former would thus appear to be propagated in a precisely identical manner with the rays of light, by a undulatory movement of the ether, while a vibratory movement of the ponderable atoms of the body would be the source of sensible heat.

The development of the mechanical theory of heat has, within a few years, made such progress that it must soon stand in the same grade with the undulatory theory of light. In proportion, at the same time, as the mathematical theory is advanced towards completion, will it become more and more practicable to reduce the explanation of the particular phenomena of heat, in a generally intelligible form, to the principles of the mechanical theory.

CONTINUOUS VIBRATORY MOVEMENT OF ALL MATTER, PONDERABLE AND IMPONDERABLE.

By L. Magrini, of the Museum of Florence.

*Translated for the Smithsonian Institution.**

It would be at once curious and instructive, could we unite in one point of view the different reflections of mankind on the phenomena of nature. What variety in ideas! what differences among men! what contrasts between nationalities! If the paths which the human mind pursues could be clearly traced, and it were possible to examine them, we should perhaps discover the reasons which cause men at one time to affirm, as if with intuitive certainty, a principle pregnant with consequences, destined to be confirmed by facts, while at other times they hesitate, go astray, and lose the truth even when earnestly seeking it.

Our senses, even with the help of the most perfect instruments, reveal to us but very little about nature; but the sensations derived from the impressions made on our organs by exterior objects are transmitted to the understanding, which co-ordinates them and draws from them the most rational and rigorous deductions; the small number of facts which our senses thus teach us, afford us the best means of extending our knowledge regarding the external world. We might repine, with some justice, at the imperfection of our senses: our ears might be more impressible, our sense of smell more susceptible; our sight might be even more piercing than it actually is with the aid of optical instruments. Yet it is not difficult to convince ourselves that it is not the senses which deceive us, and that the error proceeds from the deductions formed by the understanding.

An oar, piercing obliquely a horizontal surface of water, appears to us to be broken at the point where it issues from the water. The eye really receives the impressions of the light as if the oar were broken. But if our mind were to conclude from this optical phenomenon that we beheld a broken oar, it would not be the eye which was in fault, but the understanding, which deceives itself by a conclusion without verifying the other characters of a broken oar. The philosophers who impute error to the eye ought, on the contrary, to regard this indication as a signal service; since, without touching on other properties—the knowledge of which does not pertain to its province—the eye does in fact faithfully represent to us the real course of the luminous rays which pass from the water into the air.

This example, and a multitude of others of the same kind which might be cited, teach us that it is very difficult for us to pronounce a correct judgment in taking our first sensations as a basis. It is necessary to wait till new facts add themselves to the old, and disclose the relations which lead to the common principle of all the phenomena of the same order. Mathematical truths are pure conceptions which obey the necessary laws of reasoning; it is not the same case with the physical sciences, the study of which rests not on axioms furnished by reason, nor on principles which can be *directly* drawn from the understanding. Nature presents us complex phenomena which we must examine minutely, in order to analyze them and discover their cause; if we would not deviate from reality and truth, we must accept the descriptive language of the sensations. The sensations furnish us the data, and the tendency which we have to attribute them to external causes, conducts us from analogy to principles. In reality, the

* From Revue des Cours Scientifiques: Paris, No. 49, Nov. 2, 1867.

world is composed of objects which we know only by the impressions they produce on our senses. Matter is the unknown principle of which they are formed, the cause of the properties which they manifest, and of the sensations which reveal them to us. But when we wish to study an object, it is proper to commence by defining it; we should therefore ask ourselves, first of all, what is the true constitution of matter?

In considering the scale of magnitudes and the extreme divisibility of bodies, we find that we can form two hypotheses on the constitution of matter. We may admit that it is divisible to infinity, and consequently conceive of a body as a continuous mass, as a veritable geometric solid; or again, we may suppose that by continuing to divide more and more the fragments of a body, we shall arrive at an ultimate particle—an atom. On this last hypothesis, matter would be but an assemblage of atoms, grouped in distinct elementary molecules, placed one beside another without touching, and endowed with the faculty of approaching to or withdrawing from one another.

If we interrogate chemistry before making a choice between these two hypotheses, it will reply that if matter is continuous, that is to say, not capable of being resolved into indivisible elements, the idea of chemical combinations becomes essentially obscure. On the contrary, all the known laws of combination become evident consequences, logical corollaries of the hypothesis which considers matter as formed by the union of a great number of small indivisible masses; it is easy, in effect, to comprehend that the atoms of two simple bodies may, in uniting, form mixed molecules and give rise to new bodies.

The propagation of heat and of light in the Torricellian vacuum and in the planetary spaces, compels us to admit the existence of another highly subtle species of matter, infinitely more diffused and universal than ponderable matter, and which we are led to consider as the principal agent of physical nature.

We shall endeavor to prove, on this occasion, that movement is a fundamental property of matter in whatsoever state it exists, ponderable or imponderable; and if movement exists to-day in all the particles of matter, it has, of necessity, always existed. Without movement it is impossible for our mind to conceive any modification whatever in the state of things. No action of bodies can be manifested without our being able to affirm that this action consists in a particular mode of movement. We shall proceed, as those who transport themselves to some elevation in order to embrace the view of a vast region, to cast a comprehensive glance on the phenomena offering more particularly the proof of the interior movement which constantly animates the molecules. Let us remark at once, that this movement is for us an ultimate fact, of which as yet we know not the reason.

Celestial mechanics has explained all the perturbations of the movement of the planets, by admitting the necessary presence of unknown orbs at the limits of the solar system; observation has verified the existence of those bodies. Thanks to numerous and complete verifications of this kind, mechanics has succeeded in rendering extremely probable, not to say absolutely certain, the principle of gravitation, and in establishing in a definitive manner the law of Newton. The law of continuity in nature forces us to admit that the same principle extends to all that exists; it governs the constitution and movements of celestial bodies; it binds the satellites to their planets and the planets to the sun; it controls all the bodies which revolve one around another within a determinate radius; it also acts on each molecule, on each atom, at minute distances which escape our gross senses and all our means of direct observation.

[The name gravitation has been given to that force or tendency of masses to approach each other with an intensity which varies inversely as the square of the distance and directly as the quantity of matter. The force which acts between the particles, though perhaps of the same character, is governed by a different law, and hence has received a different name, that of cohesion.—J. H.]

But if the dimensions of molecules are extremely small, the distances which separate them are relatively very great, insomuch that, according to the suggestive idea of Laplace, a molecule may be compared to a star, and molecular gravitation to universal gravitation. It results from this that the movements of molecules may be compared to the movements of the stars, and it is thus that modern physics has raised itself to the height of mechanics. It is interesting to see a solid body suddenly obey the laws of attraction at the moment when it enters within the sphere of influence of a liquid; the effect is still produced when the liquid does not moisten the solid.

Cohesion, which may be considered a modification of gravitation, acts with different degrees of intensity on different bodies. All the degrees of intensity which separate the least dense fluid from the most condensed solid, form only some of the intermediate terms of an indefinite series, of which the ultimate parts, eminently solid, the ponderable atoms represent one of the extremities; at the other are found the matter of the nebulæ and the molecules of the ether itself. It is these ponderable atoms, subject as they all are to the attraction of the neighboring atoms and to that of the ether which surrounds them with a species of atmosphere, that produce thermal, electrical, and optical phenomena.

Under the relatively variable influence of these phenomena, bodies must continually undergo modifications in their internal structure. In effect, what varieties of forms invest quartz and feldspar in their slow and gradual passage from a vitreous to a tophaceous state! And not only stones, originally resistant, which become friable, but flexible substances which become more and more rigid; calcareous concretions which from a fibrous texture acquire a lamellar texture; siliceous incrustations, primitively friable, which are transformed into a fibrous tissue, &c.; are there not here positive proofs that, even in the most compact bodies, the molecular grouping undergoes incessant transformations? In these continual transformations, we cannot neglect the action of gravitation. Pictet has evinced it by showing the shortening which a metallic rod undergoes by resting vertically on its lower extremity. It is known, also, that the sheets of lead with which the roofs of certain buildings are covered grow thinner with time in their upper part, and become denser in their lower part. Hence it results that the particles of a metal tend, like those of a liquid, to place themselves on a level, by yielding slowly, but in a continuous manner, to the force of terrestrial gravitation.

Oil placed in a mixture of water and alcohol, having the same density with itself, is subject only to the molecular attraction of its own matter, and of the medium in which it displaces its bulk without mingling therewith. It maintains itself in equilibrium and keeps the position in which it is placed; being thus withdrawn from the terrestrial gravitation, it takes the spherical form which satisfies all the conditions of a force acting equally in all directions.

Among the expedients which enabled M. Plateau to obtain a certain number of geometrical figures under the influence of the molecular attraction, I will cite one which led to effects truly curious. If, through one of the small spheres of oil placed in a mixture of water and alcohol, we pass a small metallic rod, to which we communicate a rotary movement, this movement is suddenly transmitted to the whole mass of oil. The little sphere, by virtue of the centrifugal force, becomes flattened in proportion as it revolves more rapidly. Such is also the cause to which we usually attribute the flattening of the terrestrial sphere. When we continue to increase the velocity of rotation, the flattening is enhanced to such a degree that the sphere grows hollow, and of a sudden separates into two parts: the interior part, which is a sphere, remains at the centre of the second part, which has the form of a ring. It is impossible to witness the formation of this ring without recalling that of Saturn, which doubtless must have formed itself after the same manner. Thus the same cause which gives rise to the limpid drops of dew which sparkle on the leaves of plants, and which com-

bines into small spheres the particles of water, has given to all the great celestial bodies their spherical form.

[This statement is scarcely correct in a critical consideration of the phenomena; the spherical form of the planets is due to the attraction of every particle of the whole body on every other, while the spherical form of the globule of oil is the result of the interaction or cohesion of the particles at the surface.—J. H.]

But, besides universal attraction, matter in masses has received, at its origin, movements of translation, and by analogy the molecules of a drop of water or of a globule of platina—which are as thinly scattered and as rare in the little space they occupy as the stars of our solar system—may be supposed to be in perpetual oscillatory revolutions, without losing anything of their stability, thanks to the nature of these movements, and to the influence of the neighboring bodies.

The astonishing phenomena of acoustics completely forestall the species of repugnance we experience in admitting that the molecules of solids can execute very rapid movements without becoming disaggregated. On seeing the violent movements which pulverulent bodies undergo, and the regular figures they describe when cast on plates of glass, metal, or wood, which are made to render a sound by scraping them with a bow; on hearing sound propagated through solid bodies more quickly than through the air, and recognizing that it suffices to impress a vibratory movement on a small portion of a rigid body in order to communicate to a considerable mass a lively agitation; on verifying that a metallic rod which is made to vibrate longitudinally undergoes contractions and elongations, condensations and dilatations, just as does a column of air which resounds in a tube; at seeing a thick beam in contact with a vibrating body of small dimensions undergo elongations which may amount to the tenth of a millimetre for a metre of length: in presence of this species of mechanical paradox, according to which simple external vibrations of so feeble a nature produce such considerable effects, we can no longer refuse to admit that the immobility in which we see the molecules of solid bodies is only apparent.

The recent experiments of Professor Graham, on the diffusion of gases through graphite, confirm the hypothesis which considers gases as masses composed of innumerable particles, of atoms spherical, solid, endowed with a perfect elasticity, and moving in all directions, but with variable velocities according to the special nature of each gas. If the substance of the vessel be porous like that of the *diffusiometer*, the atoms of the gas, under the influence of the active force which animates them, are projected through the pores of the graphite, real *tunnels*, as they are in comparison with the minute dimensions of the elementary atoms of the gaseous body, which thus, in the end, escapes and disperses itself in the exterior atmosphere. But, at the same time, the air or some exterior gas enters in like manner into the interior and replaces the gas which issued from it. We may well conceive that this same atomic movement, accelerated by heat and retarded by cold, may be the cause of the elastic force of all gaseous substances and of their reaction against all compressing actions. It is known that no alteration in these movements is manifested when the same gas exists at the interior and at the exterior of the vessel, and consequently in contact with both faces of the porous wall. It may be assumed in this case that the gaseous molecules enter and issue exactly in the same proportions, and thus undergo changes of place which we can neither perceive by variations in volume nor by any other phenomenon.

If the gases which are in communication are of different natures, but possess nearly the same density, and are animated by molecular movements of the same velocity, there is again a simple displacement of molecules without augmentation of volume, as experiment has shown in the case of nitrogen and the oxide of carbon. If, on the contrary, the gases separated by the porous wall are of different density and molecular velocity, the reciprocal penetration ceases to be equal in

the two directions. The time which equal volumes of different gases occupy in passing through the graphite are approximately proportional to the square roots of their respective densities. Moreover, as the observed phenomena prove that the duration of the passage of the gases through the lamina of graphite bears no relation to the time necessary for capillary transpiration, it must be concluded that the penetration of the gases through the pores of the graphite is owing to their proper molecular movements. The diffusion of which we speak affords us the most simple example of molecular movements, and renders them, so to speak, visible by the variations of volume.

From the foregoing it would appear that the pores of graphite are of so great tenuity that there can be neither transpiration nor passage in mass of elastic fluids, and the graphite may thus be considered a sort of sieve which allows only the individual molecules to pass.

The most ordinary observation constantly teaches us that animal and vegetable matter, exposed after death to the contact of the air or buried in the earth, undergoes numerous transformations. Fermentation, putrefaction, and slow combustion are the three natural phenomena which co-operate for the accomplishment of the disaggregation of organized matter, a disaggregation necessary for the perpetuation of life on the surface of the globe.

The most recent experiments of M. Pasteur lead us to recognize that the life which is manifested in the very lowest organized productions, is indispensable to the accomplishment of the three phenomena which complete the metamorphoses of organized matter. The life of those inferior organisms presents this peculiar character, that it has no need of air or of free oxygen; a peculiarity which was unknown before the investigations of M. Pasteur. It has not been long since this eminent French chemist established experimentally that the slow combustion of which dead organic substances become the seat, when exposed to the contact of the air, stand, in the greatest number of cases, in close connection with the presence of living beings pertaining to the inferior classes of the organic kingdom. From this fact it flows, as a general consequence, that life presides at the work of death in all its phases, and that the three terms of this perpetual restoration to the atmospheric air and to the mineral kingdom of the principles which vegetables and animals have extracted from them are correlatives of the development and multiplication of organized beings.

How is it possible, after this, to refuse to admit that all nitrogenated plastic substances may acquire, under the influence of a direct oxydation, a force characterized by an internal movement, suited for being communicated to organic substances? The solid crust of our globe, the waters which cover it and the atmosphere which surrounds it, were they deprived of all proper molecular movement, would still be agitated constantly and in all their parts, under the sole influence, continually variable as it is, of the solar rays which produce light, heat, and chemical action. We are thus led to consider the activities of subtile matter and the admirable phenomena of which it is the seat. How manifold and energetic are the modifications produced by this subtle matter, in the state of light, on all the bodies of nature.

Every one knows that phosphorus becomes red in nitrogen, in hydrogen and in the barometric vacuum, under the sole influence of light; that, under this same influence, the sulphate of mercury contained in a close vessel becomes black, sealing wax grows white, bismuth acquires a violet tint, certain white crystals become gradually purple; that the iodides, the bromides, the chlorides, undergo rapid alteration, &c It is to this property possessed by light of determining, in both solids and liquids, different molecular groupings, that we owe the wonderful art of reproducing and fixing the image of persons and objects that are dear to us, with all the rigor of truth, and, so to speak, with the rapidity of thought.

These phenomena, and a great number of others which light produces on inorganic bodies, as well as on animals and vegetables, are due to vibratory

movements of the atoms of luminous bodies and the undulations of the ether which are the consequence thereof. The hypothesis of undulations has received, in recent times, the support of facts and of analysis to such an extent that it may be regarded as the true expression of a physical law, and be recognized in science with the same certainty as the theory of gravitation. How curious an object of meditation is light considered as an agent producing continual modifications on the earth and in the air, in organic tissues and in minerals! In this point of view, light appears as the effect of an initial force, capable of producing, in a mediate or immediate manner, other modes of action, such as chemical and calorific effects.

It is generally considered that an incandescent combustible body is an assemblage of molecules undergoing separation of their constituent elements in order to reunite with other molecules which they encounter in the air; that all the parts of an ignited body are subjected to violent movements, and that the atoms of every luminous body are in an analogous state of agitation. Atoms have the faculty of transmitting their movements to the neighboring particles of the ether, which, in turn, communicate them to the surrounding particles, and thus these movements are propagated to the greatest distances with the rapidity of lightning. Thus the ether only becomes luminous because the incandescent bodies and stars have arrived above the horizon and impress undulatory movements on its particles. It is for a like reason that at night our apartments and halls become as well illuminated as by day; when left in darkness it is only from the absence of a body capable of impressing on the ether contained in the hall a movement sufficiently intense to excite our visual organ.

It is proper to remark that the movement of the either impinging upon bodies is calculated to impress on their ponderable atoms regular vibrations, but vibrations more and more feeble as the distance traversed by the undulation is greater and the diffusion it has undergone more considerable. Vibrations of the second order by which ponderable bodies are thus animated may, in their turn, impress on the surrounding ether undulations less and less intense; by the same mechanism vibrations of the third and fourth order may render objects which are opaque for us visible to other more impressible beings, and, indeed, exert influences capable of modifying the molecular structure of solid bodies.

If hesitation be felt in admitting these principles, let it be remarked only that the vibrations of a tuning-fork continue to be perceptible long after the concussions of the bow or stick have ceased to be directly communicated; let it be considered, also, that when the instrument has lost the property of directly manifesting its vibrations to the ear, they do not the less exist, and may be rendered perceptible by placing it on a suitable sounding-board. It cannot then be unreasonable to admit that bodies struck by light during the day should receive in their atoms a corresponding vibratory movement, a movement which persists in darkness and is communicated to the surrounding ether. If gypsum, the diamond, and other bodies exposed to the solar rays acquire the property of becoming visible for some time in the dark, where is the explanation of this phenomenon to be sought if not in the persistence of the atomic vibrations after the exciting force has ceased to act? Can any other cause be attributed to the mysterious images of Moser? Is it not probable, from these considerations, that vibrations insensible to the retina of the human eye may produce an energetic action on the visual organ of certain animals? It is highly probable that the antennæ of some insects receive impressions of which we have no precise idea, while these creatures are insensible to the impressions which affect our organs; their sensations, perhaps, commencing at the point where ours cease.

It is impossible to conceive at any point of our globe, which changes its position at every instant in relation to the sun, the same temperature during two consecutive moments; hence there results a continual change in the molecules of all bodies. The astronomer Cesaris, by observing at several intervals the

walls of the observatory of Milan with very delicate instruments, found them to be subject to certain periodical and variable oscillations due to the action of the sun. Fabbroni made the observation on a church of Paris, and to the same cause is attributed the periodical movement which Vicat observed in the arches of the bridge of Souillac.

[Professor Horsford has found that the top of the high tower which constitutes the Bunker Hill monument, near Boston, inclines towards the west in the morning, towards the north at midday, and towards the east in the afternoon. These movements are evidently due to the expanding influence of the sun as it warms in succession the different sides of the structure. A similar but more marked effect is produced on the dome of the Capitol at Washington, as indicated by the apparent motion of the bob of a long plumb-line fastened to the under side of the roof of the rotunda and extending to the pavement beneath. This bob describes daily an elipsoidal curve, of which the longer diameter is four or five inches in length. By molecular actions of this kind, perpetually continued, time, "the slow but sure destroyer," levels with the ground the loftiest monuments of human pride.—J. H.]

But in what consists the mode of action of heat? In order to advance one step in the solution of the question, it is necessary to recall the fact that in every instance where there is a consumption of mechanical labor there is a production of heat. Attrition, compression, torsion, are each an expenditure of labor, and give rise to heat. A band of caoutchouc suddenly stretched grows warm; a strip fixed in a vice by one of its extremities, while the free extremity is made to oscillate, becomes hot at the point where it is fixed, that is to say, at the very point at which the brisk force is annihilated. And, *vice versa*, when heat is consumed labor is created; a gas, in dilating, presses a piston and becomes colder; the same effect ensues when vapor expands. The band of caoutchouc, which developed heat when suddenly stretched, creates labor and grows cool when we abandon it to its previous contraction.

When we are producing a vacuum under a bell glass, the internal air, through its elasticity, presses the strata near the channel of evacuation; thus labor is generated, and the thermometer will be seen, in effect, to indicate a lowering of temperature. If we now permit the external air to re-enter, it will compress the air which has remained in the bell, and will lose the movement by which it was animated. In this experiment, then, there is an expenditure of labor; hence, the thermometer will be found to indicate an elevation of temperature. We have been led by careful experiments to the following principle: "When equal quantities of mechanical labor are produced by causes purely thermic, there is a disappearance of equal quantities of heat, whatever be the manner of operating; reciprocally there is a production of equal quantities of heat whenever equal quantities of mechanical labor are transformed into effects purely molecular." The constancy of the relation between the labor produced and the labor consumed, whatever be the body which serves as a vehicle for this transformation, has been proved by the experiments of Grove, of Joule, of Laboulaye, and other savants. We are led to conclude from this that heat is nothing else than an active molecular force.

How can we do otherwise than admit that this singular transmutation of action, this surprising transformation of force, depends on vibrations of the molecules of heated bodies, capable of producing in the ether corresponding undulations, which are capable in their turn of causing vibrations in the molecules of the bodies on which they fall? Light and heat are modifications of the same mechanical principle; this, the capital experiments of Melloni have proved. These experiments have led to the following unforseen results: "That a luminous source (the sun, the flame of a lamp) emits at the same time different species of calorific rays, distinguishable from one another by the greater or less facility with which they traverse certain diathermic substances." We now know that these calorific

rays are characterized by differences of refrangibility or of velocity analogous to those which distinguish from one another the colors which compose white light, and these differences have been proved as rigorously in regard to heat as to light.

These specific qualities of calorific rays correspond to the lengths of different vibrations which are propagated in the homogeneous ether, or in the void spaces of ponderable matter, and which are capable of being transmitted more or less easily in diathermic mediums, according to the nature and density of the latter. The calorific waves are analogous to the sonorous waves which are propagated in the air, and which cause the elastic bodies with which they come in contact to vibrate.

The invisibility of calorific rays in nowise diminishes the great probability of the hypothesis which considers light and heat as modifications of the same mechanical principle. In fact, visibility and invisibility depend solely on the conformation of our eye, (capable of responding only to determinate molecular movements,) and not on the nature of the force which produces the luminous and calorific sensations.

The limited impressibility of our retina prevents us from perceiving the chemical rays situated beyond the violet extremity of the spectrum and the calorific rays placed beyond the red extremity. The former are constituted by vibrations too rapid and waves too short, the second by vibrations too slow and waves too long. But it is not certain that these two kinds of vibrations may not be visible for other living beings. What do we know of the perceptions which conduct the carrier-pigeon to its distant home, or of those which affect the antennæ of the insect and apprise it of danger? What of the telescopic view of the vulture, which precipitates itself towards its prey before it even appears to our eyes as a visible point on the horizon? We are compelled to admit that, on the earth, in the air, and in the water there are beings so organized as to perceive sounds inaudible to our ears, as well as luminous rays and colors of which we have no idea. Our perceptions and faculties are limited to a very small portion of the immense chain of existences which stretches between the Creator and nothing.

We believe it would be difficult to find a natural phenomenon which does not give rise to a development of electricity. Both mechanical and chemical actions, both light and heat, produce electricity. Thus, though it occasions numerous phenomena completely different from the other manifestations of the activity of matter, electricity is found to be so intimately connected with those other phenomena that we are led to admit that it depends also on the same mechanical principle as heat and light. The experiments of Nairne, confirmed by those of M. Becquerel, have taught us that metallic wires traversed by an electrical discharge, incapable of melting but sufficient to redden them, become shorter at the same time that their diameter is increased. Such wires, when traversed by a certain number of electric discharges, take an undulatory form which indicates a movement of the molecules of the wire perpendicularly to its length. Van Marum, towards the close of the last century, caused the discharge of his gigantic battery to pass through a tin wire placed horizontally on a sheet of paper. Under this action the wire was dissipated, leaving on the paper yellow traces, transversely disposed as regards the direction of the discharge; each of these traces had a peculiar texture, and all were arranged symmetrically at distances equal or multiple as among themselves. Some years earlier, Beccaria had made analogous experiments, and had interpreted the results by referring them to the principle of vibrations.

My own investigations have also been directed to this interesting subject, and I propose, on the present occasion, to repeat before my auditors the experiments of this kind which I have instituted, and to reproduce the results which I had the honor of submitting to the physicists of the ninth reunion of Italian savants at Venice.

On causing the discharge to pass through a gilt thread of silk, certain parts of

this thread remain covered with gold after the passage of the electricity These parts are at equal distances, or distances which are multiples of one another, and these distances vary with the intensity of the discharge. The gold which is seen still adhering to the silk thread must have been less agitated than that which has undergone volatilization; here, therefore, were the points of minimum agitation.

By substituting for the threads of gilt silk strips of tin, maintained in place between two glasses, analogous effects are obtained. Under the influence of the discharge the particles undergo fusion, impressing their traces on the glasses. We then discover an innumerable quantity of small and very fine filaments, which group themselves around the strip like the filings of iron around the poles of a magnet.

Sometimes, from the point of the explosion shoot in all directions rectilinear trails of a copper color and semi-transparent, forming a sort of divergent rays constituted by metallic particles reduced to a state of extreme tenuity by the discharge. Examined with the microscope these trails are of a structure truly exquisite, and are disposed with admirable symmetry on each side of the central band, along the length of which are to be observed points of maximum and of minimum intensity. A series of figures thus obtained are annexed: different systems of linear filaments, of circular figures, of elliptical figures, continuous and discontinuous, affording a beautiful exemplification of the coexistence in the same body of several kinds of movement, preserving their individual character in all its integrity.

It is quite surprising to see that certain of the electric rays arriving on the edge of the glasses, between which the strips of tin are confined, rebound on the surface of separation of the two mediums, and are reflected in making an angle of reflection equal to the angle of incidence.

Is it possible, at sight of these figures, not to admit that the metallic vapor thus distributed has been subjected to a vibratory agitation, to a species of undulatory movement? Nothing can be more beautiful than these fine and granulated curves which cross each other in a thousand ways on the interior faces of the glass, and along which are disposed very minute metallic particles, visible, however, to the naked eye when looked at on being transferred to the diffused light of heaven. We are forced by this to conclude that the vibratory movement is transmitted by waves which increase as they are propagated, which are reflected to the surface of separation of the two mediums, and which reveal to the eye the route traversed by the reflected wave.

The discoveries of Faraday on the *relation of magnetism to light*, on the *illumination of magnetic lines*, and on *diamagnetism*, the sounds which, according to the obserations of Wertheim, of De la Rive, as well as my own, accompany temporary magnetism and interrupted currents, are phenomena of the same order, tending to prove that the forces of matter are in a reciprocal dependence so intimate that they are capable of producing one another by equivalent quantities.

But the intervention of determinate conditions for the production of such or such a kind of movement is necessarily subordinate to the pre-existence, in every species of matter, of a molecular agitation which, under the influence of the different circumstances we have passed in review, may take any character whatever, pass from one species of movement to another, or be added to other movements which may exist at the same time in the same body, and thus give rise to luminous, calorific, electro-magnetic or chemical phenomena, or to all these movements at once.

Thus we are led to admit, in the atoms of ponderable bodies, and with still stronger reason in the particles of imponderable matter, an interior movement, a primordial property—that is to say, a general property which has always existed.

The intensity of this interior agitation varies with the nature and dimensions of the body, with the volume and density of the atoms, with their individual

separation within the limits of their appropriate agitation. The nature of this movement must vary with the nature of the bodies, each of them having a particular movement which constitutes its normal state and impresses on it a special character. We can comprehend, therefore, that when two bodies are placed in contact, there must be a communication, a transference of their oscillatory and rotary movements, with loss on the one side and gain on the other. Let us take an example: suppose the initial molecular movement of copper to be more intense than that of zinc; if the copper comes into collision with the zinc it will lose, according to the laws of mechanics, a part of its inherent force equal to that which the zinc acquires. We conclude hence that the copper, considered as the colliding body, is negative, while the assailed zinc is positive.

Would it be rational to suppose that mechanical laws are true when perceptible masses are in question, and yet control neither atoms nor the particles of subtile matter? If it be true that there is nothing *absolutely large* nor *absolutely little* in creation, dimensions can never constitute a difference in relation to the forces which produce and the laws which govern phenomena. We consider then the action of light on the object which it renders visible, and that of heat which elevates its temperature, as something of an analogue to the sympathetic vibration of a chord at the moment when the sound of another chord traverses the air. After an analogous manner, all actions at a distance and electro-magnetic inductions present themselves as natural consequences of one same mechanical principle, conformably to the general economy of the system of the universe.

One of the most important consequences of this study is that sound, light, heat, electricity,* are not real entities, but simply modes of action and movements of matter communicated to our brain through the medium of the nerves. The human organism may therefore be considered as an elastic system, of which the different parts receive the shocks of elastic mediums, and vibrate in unison with a certain number of undulations each of which produces its complete effect independently of others. Here science stops! The mysterious influence of matter on mind we must be content to regard as a secret which will yet be long hidden from us.

Be it remarked that in the order of animated beings there are those which might be clustered in myriads on the point of a needle, and which live but a few seconds; and yet to them their life seems long and complete, and during those few seconds they may have a perception of millions of shocks such as those which constitute heat. There may very probably exist other beings which can never have a perception of a complete undulation of the ether, and which scarcely distinguish a feeble portion of one; in fine, even these elementary portions will always appear too complex to certain other beings which perceive nothing but the individual movements and displacements of atoms. These considerations enable us to appreciate how very limited are our senses, for, as has just been seen, the human race occupies but a few degrees of the indefinite scale of sensibility. Herein, perhaps, is one of the principal motives why man is often diverted from truth, even while seeking it; the instinctive repugnance which he feels to meditate upon simple and common phenomena, and to extend the laws which govern the domain that he is able to explore beyond the limits of his own sensibility, has led him to imagine complicated systems and to have recourse to the hypothesis of mysterious principles.

These reflections lead us to another important consequence, namely, that if the philosophers who have considered our world as an atom in creation are right, under a certain point of view, we ought yet to recognize, with other philosophers, that each atom is a world. Each atom possesses a proper activity, and is the seat of all the natural forces; these never manifest themselves outside of matter,

[* The author is not warranted by the present state of science to include electricity in the same class with sound, light, and heat. In statical electrical repulsion, which manifests itself at a great distance, we have a phenomenon entirely unlike any effect exhibited by sound, light, or heat.—J. H.]

and matter without these forces is a pure abstraction. If there were but a single atom in the universe, it would always remain identical with itself; but the tendency of each atom to maintain its original activity is continually countervailed by the action of other atoms and the undulations of the ether. We are hence forced to admit that *inertia* and *activity* are two facts inseparable from matter. We all know that in bodies which revolve upon an axis, inertia is manifested by a tendency of the particles to withdraw from that axis, a tendency which varies in intensity with the velocity of the rotation. We may equally admit that in the molecular groups which constitute bodies, the force antagonistic to molecular gravitation is nothing else than the centrifugal force due to a rotary movement of each of the molecules around the centre of gravity of the group, and variable with the velocity of the molecules themselves, a velocity which is proportional to their temperature.

Since heat generates electricity, either directly or indirectly, and electricity heat; since all other forces are transformed among themselves and are resolved into different forms of movement, we must thence necessarily conclude that any phenomena whatsoever *can only proceed from the varied evolutions of the primordial force which the Creator has given to matter, of which it is the active and inseparable principle;* as to the nature of that force it will, perhaps, always be hidden to the humani ntellect.

RADIATION.

By John Tyndall.*

I.—VISIBLE AND INVISIBLE RADIATION.

Between the mind of man and the outer world are interposed the nerves of the human body, which translate, or enable the mind to translate, the impressions of that world into facts of consciousness and thought.

Different nerves are suited to the perception of different impressions. We do not see with the ear, nor hear with the eye, nor are we rendered sensible of sound by the nerves of the tongue. Out of the general assemblage of physical actions, each nerve, or group of nerves, selects and responds to those for the perception of which it is specially organized.

The optic nerve passes from the brain to the back of the eye-ball and there spreads out, to form the retina, a web of nerve filaments, on which the images of external objects are projected by the optical portion of the eye. This nerve is limited to the apprehension of the phenomena of radiation, and, notwithstanding its marvellous sensibility to certain impressions of this class, it is singularly obtuse to other impressions.

Nor does the optic nerve embrace the entire range even of radiation. Some rays, when they reach it, are incompetent to evoke its power, while others never reach it at all, being absorbed by the humors of the eye. To all rays which, whether they reach the retina or not, fail to excite vision, we give the name of invisible or obscure rays. All non-luminous bodies emit such rays. There is no body in nature absolutely cold, and every body not absolutely cold emits rays of heat. But to render radiant heat fit to affect the optic nerve a certain temperature is necessary. A cool poker thrust into a fire remains dark for a time, but when its temperature has become equal to that of the surrounding coals it glows like them. In like manner, if a current of electricity of gradually increasing strength be sent through a wire of the refractory metal platinum, the wire first becomes sensibly warm to the touch; for a time its heat augments, still, however, remaining obscure; at length we can no longer touch the metal with impunity; and at a certain definite temperature it emits a feeble red light. As the current augments in power the light augments in brilliancy, until finally the wire appears of a dazzling white. The light which it now emits is similar to that of the sun.

By means of a prism Sir Isaac Newton unravelled the texture of solar light, and by the same simple instrument we can investigate the luminous changes of our platinum wire. In passing through the prism all its rays (and they are infinite in variety) are bent or refracted from their straight course; and as different rays are differently refracted by the prism, we are by it enabled to separate one class of rays from another. By such prismatic analysis Dr. Draper has shown that when the platinum wire first begins to glow the light emitted is a pure red. As the glow augments the red becomes more brilliant, but at the same time orange rays are added to the emission. Augmenting the temperature still further, yellow rays appear beside the orange; after the yellow, green rays are emitted; and after the green come, in succession, blue, indigo, and violet rays.

* The Rede Lecture, delivered in the senate house, before the university of Cambridge, England, May 16, 1865.

To display all these colors at the same time the platinum wire must be *white-hot;* the impression of whiteness being in fact produced by the simultaneous action of all these colors on the optic nerve.

In the experiment just described we began with a platinum wire at an ordinary temperature, and gradually raised it to a white heat. At the beginning, and before the electric current had acted at all upon the wire, it emitted invisible rays. For some time after the action of the current had commenced, and even for a time after the wire had become intolerable to the touch, its radiation was still invisible. The question now arises, What becomes of these invisible rays when the visible ones make their appearance? It will be proved in the sequel that they maintain themselves in the radiation; that a ray once emitted continues to be emitted when the temperature is increased, and hence the emission from our platinum wire, even when it has attained its maximum brilliancy, consists of a mixture of visible and invisible rays. If, instead of the platinum wire, the earth itself were raised to incandescence, the obscure radiation which it now emits would continue to be emitted. To reach incandescence the planet would have to pass through all the stages of non-luminous radiation, and the final emission would embrace the rays of all these stages. There can hardly be a doubt that from the sun itself rays proceed similar in kind to those which the dark earth pours nightly into space. In fact, the various kinds of obscure rays emitted by all the planets of our system are included in the present radiation of the sun.

The great pioneer in this domain of science was Sir William Herschel. Causing a beam of solar light to pass through a prism, he resolved it into its colored constituents; he formed what is technically called the solar spectrum. Exposing thermometers to the successive colors he determined their heating power, and found it to augment from the violet or most refracted end to the red or least refracted end of the spectrum. But he did not stop here. Pushing his thermometers into the dark space beyond the red, he found that, though the light had disappeared, the radiant heat falling on the instruments was more intense than that at any visible part of the spectrum. In fact, Sir William Herschel showed, and his results have been verified by various philosophers since his time, that besides its luminous rays, the sun pours forth a multitude of other rays more powerfully calorific than the luminous ones, but entirely unsuited to the purposes of vision.

At the less refrangible end of the solar spectrum, then, the range of the sun's radiation is not limited by that of the eye. The same statement applies to the more refrangible end. Ritter discovered the extension of the spectrum into the invisible region beyond the violet; and, in recent times, this ultra-violet emission has had peculiar interest conferred upon it by the admirable researches of Professor Stokes. The complete spectrum of the sun consists, therefore, of three distinct parts: 1st, of ultra-red rays of high heating power, but unsuited to the purposes of vision; 2d, of luminous rays which display the following succession of colors: red, orange, yellow, green, blue, indigo, violet; 3d, of ultra-violet rays which, like the ultra-red ones, are incompetent to excite vision, but, unlike them, possess a very feeble heating power. In consequence, however, of their chemical energy, these ultra-violet rays are of the utmost importance to the organic world.

II.—ORIGIN AND CHARACTER OF RADIATION. THE ETHER.

When we see a platinum wire raised gradually to a white heat and emitting in succession all the colors of the spectrum, we are simply conscious of a series of changes in the condition of our eyes. We do not see the actions in which these successive colors originate, but the mind irresistibly infers that the appearance of the colors corresponds to certain contemporaneous changes in the wire.

What is the nature of these changes? In virtue of what condition does the wire radiate at all? We must now look from the wire as a whole to its constituent atoms. Could we see those atoms, even before the electric current has begun to act upon them, we should find them in a state of vibration. In this vibration indeed consists such warmth as the wire then possesses. Locke enunciated this idea with great precision, and it seems placed beyond the pale of doubt by the excellent quantitative researches of Mr. Joule. "Heat," says Locke, "is a very brisk agitation of the insensible parts of the object, which produce in us that sensation from which we denominate the object hot; so what in our sensation is *heat* in the object is nothing but *motion*." When the electric current, still feeble, begins to pass through the wire, its first act is to intensify the vibrations already existing, by causing the atoms to swing through wider ranges. Technically speaking, the *amplitudes* of the oscillations are increased. The current does this, however, without altering the *period* of the old vibrations, or the time in which they were accomplished. But, besides intensifying the old vibrations, the current generates new and more rapid ones, and when a certain definite rapidity has been attained the wire begins to glow. The color first exhibited is red, which corresponds to the lowest rate of vibration of which the eye is able to take cognizance. By augmenting the strength of the electric current, more rapid vibrations are introduced, and orange rays appear. A quicker rate of vibration produces yellow, a still quicker green, and by further augmenting the rapidity we pass through blue, indigo, and violet, to the extreme ultra-violet rays.

Such are the changes which science recognizes in the wire itself, as concurrent with the visual changes taking place in the eye. But what connects the wire with this organ? By what means does it send such intelligence of its varying condition to the optic nerve? Heat being, as defined by Locke, "a very brisk agitation of the insensible parts of an object," it is readily conceivable that on *touching* a heated body the agitation may communicate itself to the adjacent nerves, and announce itself to them as light or heat. But the optic nerve does not touch the hot platinum, and hence the pertinence of the question, By what agency are the vibrations of the wire transmitted to the eye?

The answer to this question involves, perhaps, the most important physical conception that the mind of man has yet achieved; the conception of a medium filling space and fitted mechanically for the transmission of the vibrations of light and heat, as air is fitted for the transmission of sound. This medium is called the *luminiferous ether*. Every shock of every atom of our platinum wire raises in this ether a wave, which speeds through it at the rate of 186,000 miles a second. The ether suffers no rupture of continuity at the surface of the eye, the inter-molecular spaces of the various humors are filled with it; hence the waves generated by the glowing platinum can cross these humors and impinge on the optic nerve at the back of the eye. Thus the sensation of light reduces itself to the communication of motion. Up to this point we deal with pure mechanics; but the subsequent translation of the shock of the ethereal waves into consciousness eludes the analysis of science. As an oar dipping into the Cam generates systems of waves, which, speeding from the centre of disturbance, finally stir the sedges on the river's bank, so do the vibrating atoms generate in the surrounding ether undulations, which finally stir the filaments of the retina. The motion thus imparted is transmitted with measurable and not very great velocity to the brain, where, by a process which science does not even tend to unravel, the tremor of the nervous matter is converted into the conscious impression of light.

Darkness might then be defined as ether at rest; light as ether in motion. But in reality the ether is never at rest, for in the absence of light-waves we have heat-waves always speeding through it. In the spaces of the universe both classes of undulations incessantly commingle. Here the waves issuing

from uncounted centres cross, coincide, oppose, and pass through each other, without confusion or ultimate extinction. The waves from the zenith do not jostle out of existence those from the horizon, and every star is seen across the entanglement of wave motions produced by all other stars. It is the ceaseless thrill which those distant orbs collectively create in the ether which constitutes what we call *the temperature of space*. As the air of a room accommodates itself to the requirements of an orchestra, transmitting each vibration of every pipe and string, so does the inter-stellar ether accommodate itself to the requirements of light and heat. Its waves mingle in space without disorder, each being endowed with an individuality as indestructible as if it alone had disturbed the universal repose.

All vagueness with regard to the use of the terms *radiation* and *absorption* will now disappear. Radiation is the communication of vibratory motion to the ether, and when a body is said to be chilled by radiation, as, for example, the grass of a meadow on a starlight night, the meaning is, that the molecules of the grass have lost a portion of their motion by imparting it to the medium in which they vibrate. On the other hand, the waves of ether once generated, may so strike against the molecules of a body exposed to their action as to yield up their motion to the latter; and in this transfer of the motion from the ether to the molecules consists the absorption of radiant heat. All the phenomena of heat are in this way reducible to interchanges of motion; and it is purely as the recipients or the donors of this motion that we ourselves become conscious of the action of heat and cold.

III.—THE ATOMIC THEORY IN REFERENCE TO THE ETHER.

The word "atoms" has been more than once employed in this discourse. Chemists have taught us that all matter is reducible to certain elementary forms, to which they give this name. These atoms are endowed with powers of mutual attraction, and under suitable circumstances they coalesce to form compounds. Thus oxygen and hydrogen are elements when separate, or merely *mixed*, but they may be made to *combine* so as to form molecules, each consisting of two atoms of hydrogen and one of oxygen. In this condition they constitute water. So also chlorine and sodium are elements, the former a pungent gas, the latter a soft metal; and they unite together to form chloride of sodium or common salt. In the same way the element nitrogen combines with hydrogen, in the proportion of one atom of the former to three of the latter, to form ammonia, or spirit of hartshorn. Picturing in imagination the atoms of elementary bodies as little spheres, the molecules of compound bodies must be pictured as groups of such spheres. This is the atomic theory as Dalton conceived it. Now, if this theory have any foundation in fact, and if the theory of an ether pervading space, and constituting the vehicle of atomic motion, be founded in fact, we may assuredly expect the vibrations of elementary bodies to be profoundly modified by the act of combination. It is on the face of it almost certain that, both as regards radiation and absorption, that is to say, both as regards the communication of motion to the ether and the acceptance of motion from it, the deportment of the uncombined will be different from that of the combined atoms.

IV.—ABSORPTION OF RADIANT HEAT BY GASES.

We have now to submit these considerations to the only test by which they can be tried, namely, that of experiment. An experiment is well defined as a question put to Nature; but to avoid the risk of asking amiss, we ought to purify the question from all adjuncts which do not necessarily belong to it. Matter has been shown to be composed of elementary constituents, by the compounding of which all its varieties are produced. But besides the chemical unions which

they form, both elementary and compound bodies can unite in another and less intimate way. By the attraction of cohesion gases and vapors aggregate to liquids and solids without any change of their chemical nature. We do not yet know how the transmission of radiant heat may be affected by the entanglement due to cohesion, and as our object now is to examine the influence of chemical union alone, we shall render our experiments more pure by liberating the atoms and molecules entirely from the bonds of cohesion, and employing them in the gaseous or vaporous form.

Let us endeavor to obtain a perfectly clear mental image of the problem now before us. Limiting, in the first place, our inquiries to the phenomena of absorption, we have to picture a succession of waves issuing from a radiant source and passing through a gas; some of them striking against the gaseous molecules and yielding up their motion to the latter; others gliding round the molecules, or passing through the inter-molecular spaces without apparent hinderance. The problem before us is to determine whether such free molecules have any power whatever to stop the waves of heat, and if so, whether different molecules possess this power in different degrees.

The source of waves which I shall choose for these experiments is a plate of copper, against the back of which a steady sheet of flame is permitted to play. On emerging from the copper, the waves, in the first instance, pass through a space devoid of air, and then enter a hollow glass cylinder three feet long and three inches wide. The two ends of this cylinder are stopped by two plates of rock salt, this being the only solid substance which offers a scarcely sensible obstacle to the passage of the calorific waves. After passing through the tube, the radiant heat falls upon the anterior face of a thermo-electric pile, where it is instantly applied to the generation of an electric current. This current conducted round a magnetic needle deflects it and the magnitude of the deflection is a measure of the heat falling upon the pile. This famous instrument, and not an ordinary thermometer, is what we shall use in these inquiries, but we shall use it in a somewhat novel way. As long as the two opposite faces of the thermo-electric pile are kept at the same temperature, no matter how high that may be, there is no current generated. The current is a consequence of a *difference* of temperature between the two opposite faces of the pile. Hence, if after the anterior face has received the heat from our radiating source, a second source, which we may call the compensating source, be permitted to radiate against the posterior face, this latter radiation will tend to neutralize the former. When the neutralization is perfect, the magnetic needle connected with the pile is no longer deflected, but points to the zero of the graduated circle over which it hangs.

And now let us suppose the glass tube, through which pass the waves from the heated plate of copper, to be exhausted by an air-pump, the two sources of heat acting at the same time on the two opposite faces of the pile. Perfectly equal quantities of heat being imparted to the two faces, the needle points to zero. Let the molecules of any gas be now permitted to enter the exhausted tube; if these molecules possess any sensible power of intercepting the calorific waves, the equilibrium previously existing will be destroyed, the compensating source will triumph, and a deflection of the magnetic needle will be the immediate consequence. From the deflections thus produced by different gases we can readily deduce the relative amounts of wave motion which their molecules intercept.

In this way the substances mentioned in the following table were examined, a small portion only of each being admitted into the glass tube. The quantity admitted was just sufficient to depress a column of mercury associated with the tube one inch: in other words, the gases were examined at a pressure of one-thirtieth of an atmosphere. The numbers in the table express the relative

amounts of wave motion absorbed by the respective gases, the quantity intercepted by atmospheric air being taken as unity.

Radiation through gases.

Name of gas.	Relative absorption.	Name of gas.	Relative absorption.
Air	1	Nitric oxide	1,590
Oxygen	1	Nitrous oxide	1,860
Nitrogen	1	Sulphide of hydrogen	2,100
Hydrogen	1	Ammonia	5,460
Carbonic oxide	750	Olefiant gas	6,030
Carbonic acid	972	Sulphurous acid	6,480
Hydrochloric acid	1,005		

Every gas in this table is perfectly transparent to light—that is to say, all waves within the limits of the visible spectrum pass through it without obstruction; but for the waves of slower period, emanating from our heated plate of copper, enormous differences of absorptive power are manifested. These differences illustrate in the most unexpected manner the influence of chemical combination. Thus the elementary gases, oxygen, hydrogen, and nitrogen, and the mixture atmospheric air, prove to be practical vacua to the rays of heat; for every ray, or, more strictly speaking, for every unit of wave motion, which any one of them is competent to intercept, perfectly transparent ammonia intercepts 5,460 units, olefiant gas 6,030 units, while sulphurous acid gas absorbs 6,480 units. What becomes of the wave motion thus intercepted? It is applied to the heating of the absorbing gas. Through air, oxygen, hydrogen, and nitrogen, on the contrary, the waves of ether pass without absorption, and these gases are not sensibly changed in temperature by the most powerful calorific rays. The position of nitrous oxide in the foregoing table is worthy of particular notice In this gas we have the same atoms in a state of chemical union that exist uncombined in the atmosphere; but the absorption of the compound is 1,800 times that of the air.

V.—FORMATION OF INVISIBLE FOCI.

This extraordinary deportment of the elementary gases naturally directed attention to elementary bodies in another state of aggregation. Some of Melloni's results now attained a new significance; for this celebrated experimenter had found crystals of the element sulphur to be highly pervious to radiant heat; he had also proved that lampblack and black glass (which owes its blackness to the element carbon) were to a considerable extent transparent to calorific rays of low refrangibility. These facts, harmonizing so strikingly with the deportment of the simple gases, suggested further inquiry. Sulphur dissolved in bisulphide of carbon was found almost perfectly transparent. The dense and deeply colored element bromine was examined, and found competent to cut off the light of our most brilliant flames, while it transmitted the invisible calorific rays with extreme freedom. Iodine, the companion element of bromine, was next thought of, but it was found impracticable to examine the substance in its usual solid condition. It, however, dissolves freely in bisulphide of carbon. There is no chemical union between the liquid and the iodine; it is simply a case of solution, in which the uncombined atoms of the element can act upon the radiant heat. When permitted to do so, it was found that a layer of dissolved iodine, sufficiently opaque to cut off the light of the mid-day sun, was almost absolutely transparent to all invisible calorific rays.

By prismatic analysis Sir William Herschel separated the luminous from the non-luminous rays of the sun, and he also sought to render the obscure rays visible by concentration. Intercepting the luminous portion of his spectrum he

brought, by a converging lens, the ultra-red rays to a focus, but by this condensation he obtained no light. The solution of iodine offers a means of filtering the solar beam, or, failing it, the beam of the electric lamp, which renders attainable more powerful foci of invisible rays than could possibly be obtained in the above experiment by Sir William Herschel; for to form his spectrum he was obliged to operate upon solar light which had passed through a narrow slit or through a small aperture, the amount of the obscure heat admitted being limited by this circumstance. But with our opaque solution we may employ the entire surface of the largest lens, and, having thus converged the rays, luminous and non-luminous, we can intercept the former by the iodine, and do what we please with the latter. Experiments of this character, not only with the iodine solution, but also with black glass and layers of lampblack, were publicly performed at the Royal Institution in the early part of 1862, and the effects at the foci of invisible rays then obtained were such as had never been witnessed previously.

In the experiments here referred to, glass lenses were employed to concentrate the rays. But glass, though highly transparent to the luminous, is in a high degree opaque to the invisible heat-rays of the electric lamp, and hence a large portion of those rays was intercepted by the glass. The obvious remedy here is to employ rock-salt lenses instead of glass ones, or to abandon the use of lenses wholly and to concentrate the rays by a metallic mirror. Both of these improvements have been introduced, and, as anticipated, the invisible foci have been thereby rendered more intense. The mode of operating remains, however, the same in principle as that made known in 1862. It was then found that an instant's exposure of the face of the thermo-electric pile to the focus of invisible rays dashed the needles of a coarse galvanometer violently aside. It is now found that on substituting for the face of the thermo-electric pile a combustible body, the invisible rays are competent to set that body on fire.

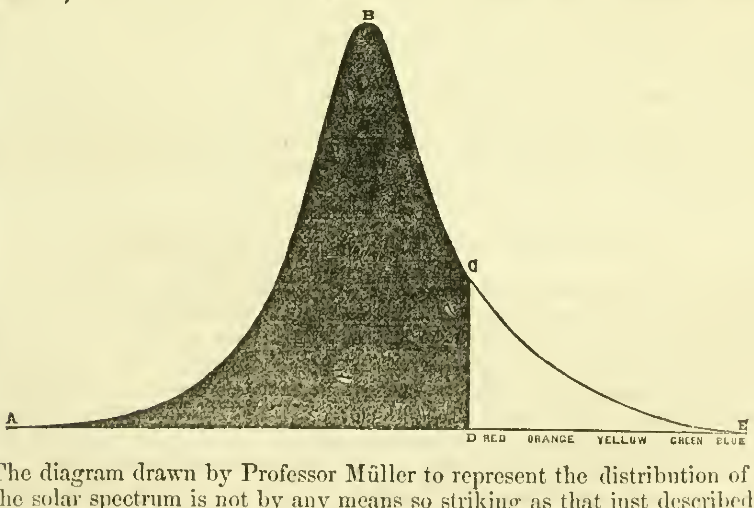
VI.—VISIBLE AND INVISIBLE RAYS OF THE ELECTRIC LIGHT.

We have next to examine what proportion the non-luminous rays of the electric light bear to the luminous ones. This the opaque solution of iodine enables us to do with an extremely close approximation to the truth. The pure bisulphide of carbon, which is the solvent of the iodine, is perfectly transparent to the luminous, and almost perfectly transparent to the dark rays of the electric lamp. Through the transparent bisulphide the total radiation of the lamp may be considered to pass, while through the solution of iodine only the dark rays are transmitted. Determining, then, by means of a thermo-electric pile, the total radiation, and deducting from it the purely obscure, we obtain the amount of the purely luminous emission. Experiments, performed in this way, prove that if all the visible rays of the electric light were converged to a focus of dazzling brilliancy, its heat would only be one-ninth of that produced at the unseen focus of the invisible rays.

Exposing his thermometers to the successive colors of the solar spectrum, Sir William Herschel determined the heating power of each, and also that of the region beyond the extreme red. Then drawing a straight line to represent the length of the spectrum, he erected, at various points, perpendiculars to represent the calorific intensity existing at those points. Uniting the ends of all his perpendiculars, he obtained a curve which showed at a glance the manner in which the heat was distributed in the solar spectrum. Professor Müller, of Freiburg, with improved instruments, afterwards made similar experiments, and constructed a more accurate diagram of the same kind. We have now to examine the distribution of heat in the spectrum of the electric light; and for this purpose we shall employ a particular form of the thermo-electric pile, devised by Melloni. Its face is a rectangle, which, by means of movable side pieces, can be rendered as narrow as desired. We can, for example, have the face of the pile the tenth, the hundredth, or even the thousandth of an inch in breadth. By means of an

endless screw, this *linear* thermo-electric pile may be moved through the entire spectrum, each of its rays being selected in succession, the amount of heat falling upon the pile at every point of its march being declared by an associated magnetic needle.

When this instrument is brought up to the violet end of the spectrum of the electric light, the heat is found to be insensible. As the pile gradually moves from the violet end towards the red, heat soon manifests itself, augmenting as we approach the red. Of all the colors of the visible spectrum the red possesses the highest heating power. On pushing the pile into the dark region beyond the red, the heat, instead of vanishing, rises suddenly and enormously in intensity, until at some distance beyond the red it attains a maximum. Moving the pile still forward, the thermal power falls, somewhat more suddenly than it rose. It then gradually shades away, but for a distance beyond the red greater than the length of the whole visible spectrum, signs of heat may be detected. Drawing, as Sir William Herschel did, a datum line, and erecting along it perpendiculars proportional in length to the thermal intensity at the respective points, we obtain the extraordinary curve which exhibits the distribution of heat in the spectrum of the electric light. In the region of dark rays beyond the red, the curve shoots up in a steep and massive peak—a kind of Matterhorn of heat, which dwarfs by its magnitude the portion of the diagram representing the luminous radiation. Indeed, the idea forced upon the mind by the inspection of this diagram is that the light rays are a mere insignificant appendage to the dark ones, thrown in as it were by nature for the purposes of vision. (See figure, where the space *ABCD* represents the non-luminous, and *CDE* the luminous radiation.)



The diagram drawn by Professor Müller to represent the distribution of heat in the solar spectrum is not by any means so striking as that just described, and the reason, doubtless, is that prior to reaching the earth the solar rays have to traverse our atmosphere. The aqueous vapor there diffused acts very energetically upon the ultra red rays, and by it the summit of the peak representing the sun's invisible radiation is cut off. A similar lowering of the mountain of invisible heat is observed when the rays from the electric light are permitted to pass through a film of water, which acts upon them as the atmospheric vapor acts upon the rays of the sun.

VII.—COMBUSTION BY INVISIBLE RAYS.

The sun's invisible rays transcend the visible ones in heating power, so that if the alleged performances of Archimedes during the siege of Syracuse had any

foundation in fact, the dark solar rays would have been the philosopher's chief agents of combustion. On a small scale we can readily produce, with the purely invisible rays of the electric light, all that Archimedes is said to have performed with the sun's total radiation. Placing behind the electric light a small concave mirror, the rays are converged, the cone of reflected rays and their point of convergence being rendered clearly visible by the dust always floating in the air. Interposing between the luminous focus and the source of rays our solution of iodine, the light of the cone is entirely cut away, but the intolerable heat experienced when the hand is placed, even for a moment, at the dark focus, shows that the calorific rays pass unimpeded through the opaque solution.

Almost anything that ordinary fire can effect may be accomplished at the focus of invisible rays, the air at the focus remaining at the same time perfectly cold, on account of its transparency to the heat-rays. An air thermometer with a hollow rock-salt bulb would be unaffected by the heat of the focus; there would be no expansion, and in the open air there is no convection. The ether at the focus, and not the air, is the substance in which the heat is embodied. A block of wood placed at the focus absorbs the heat, and dense volumes of smoke rise swiftly upwards, showing the manner in which the air itself would rise if the invisible rays were competent to heat it. At the perfectly dark focus dry paper is instantly inflamed; chips of wood are speedily burnt up; lead, tin, and zinc are fused; and discs of charred paper are raised to vivid incandescence. It might be supposed that the obscure rays would show no preference for black over white, but they do show a preference, and to obtain rapid combustion, the body, if not already black, ought to be blackened. When metals are to be burned, it is necessary to blacken or otherwise tarnish them, so as to diminish their reflective power. Blackened zinc foil, when brought into the focus of invisible rays, is instantly caused to blaze, and burns with its peculiar purple flame. Magnesium wire flattened, or tarnished magnesium ribbon, also bursts into splendid combustion. Pieces of charcoal suspended in a receiver full of oxygen are also set on fire, the dark rays after having passed through the receiver still possessing sufficient power to ignite the charcoal, and thus initiate the attack of the oxygen. If, instead of being plunged in oxygen, the charcoal be suspended in vacuo, it immediately glows at the place where the focus falls.

VIII.—TRANSMUTATION OF RAYS: CALORESCENCE.*

Eminent experimenters were long occupied in demonstrating the substantial identity of light and radiant heat, and we have now the means of offering a new and striking proof of this identity. A concave mirror produces beyond the object which it reflects an inverted and magnified image of the object; withdrawing, for example, our iodine solution, an intensely luminous inverted image of the carbon points of the electric light is formed at the focus of the mirror employed in the foregoing experiments. When the solution is interposed and the light is cut away, what becomes of this image? It disappears from sight, but an invisible thermograph remains, and it is only the peculiar constitution of our eyes that disqualifies us from seeing the picture formed by the calorific rays. Falling on white paper, the image chars itself out; falling on black paper, two holes are pierced in it, corresponding to the images of the two coal points; but falling on a thin plate of carbon in vacuo, or upon a thin sheet of platinized plantinum, either in vacuo or in air, radiant heat is converted into light, and the image stamps itself in vivid incandescence upon both the carbon and the metal. Results similar to those obtained with the electric light have also been obtained with the invisible rays of the lime light and of the sun.

Before a Cambridge audience, it is hardly necessary to refer to the excellent researches of Professor Stokes at the opposite end of the spectrum. The above

* I borrow this term from Professor Challis, *Philosophical Magazine*, vol. xii., p. 521.

results constitute a kind of complement to his discoveries. Professor Stokes named the phenomena which he has discovered and investigated, *Fluorescence;* for the new phenomena here described, I have proposed the term *Calorescence.* He, by the interposition of a proper medium, so lowered the refrangibility of the ultra-violet rays of the spectrum as to render them visible; and here, by the interposition of the plantinum foil, the refrangibility of the ultra-red rays is so exalted as to render them visible. Looking through a prism at the incandescent image of the carbon points, the light of the image is decomposed and a complete spectrum obtained. The invisible rays of the electric light, remolded by the atoms of the platinum, shine thus visibly forth—ultra-red rays being converted into red, orange, yellow, green, blue, indigo, and ultra-violet ones. Could we, moreover, raise the original source of rays to a sufficiently high temperature, we might not only obtain from the dark rays of such a source a single incandescent image, but from the dark rays of this image we might obtain a second one, from the dark rays of the second a third, and so on—a series of complete images and spectra being thus extracted from the invisible emission of the primitive source.*

IX.—DEADNESS OF THE OPTIC NERVE TO THE CALORIFIC RAYS.

The layer of iodine used in the foregoing experiments, when placed before the eye, intercepted the light of the noonday sun. No trace of light from the electric lamp was visible, even in the darkest room, when a white screen was placed at the focus of the mirror. It was thought, however, that if the retina itself were brought into the focus the sensation of light might be experienced. The danger of this experiment was twofold. If the dark rays were absorbed in a high degree by the humors of the eye the albumen of the humors might coagulate along the line of the rays. If, on the contrary, no such high absorption took place, the rays might reach the retina with a force sufficient to destroy it. To test the likelihood of these results experiments were made on water and on a solution of alum, and they showed it to be very improbable that in the brief time requisite for an experiment any serious damage could be done. The eye was, therefore, caused to approach the dark focus, no defence in the first instance being provided; but the heat acting upon the parts surrounding the pupil could not be borne. An aperture was therefore pierced in a plate of metal, and the eye placed behind the aperture was caused to approach the point of convergence of invisible rays. The focus was attained, first by the pupil and afterwards by the retina. Removing the eye, but permitting the plate of metal to remain, a sheet of platinum foil was placed in the position occupied by the retina a moment before. The platinum became red-hot. No sensible damage was done to the eye by this experiment; no impression of light was produced; the optic nerve was not even conscious of heat.

But the humors of the eye are known to be highly impervious to the invisible calorific rays, and the question therefore arises, "did the radiation in the fore-

* On investigating the calorescence produced by rays transmitted through glasses of various colors, it was found that in the case of certain specimens of blue glass the platinum foil glowed with a *pink* or *purplish* light. The effect was not subjective, and considerations of obvious interest are suggested by it. Different kinds of black glass differ notably as to their power of transmitting radiant heat. In thin plates some descriptions tint the sun with a greenish hue; others make it appear a glowing red without any trace of green. The latter are by far more diathermic than the former. In fact, carbon, when perfectly dissolved, and incorporated with a good white glass, is highly transparent to the calorific rays, and by employing it as an absorbent, the phenomena of "calorescence" may be obtained, though in a less striking form than with the iodine. The black glass chosen for thermometers, and intended to absorb completely the solar heat, may entirely fail in this object if the glass in which the carbon is incorporated be colorless. To render the bulb of a thermometer a perfect absorbent, the glass with which the carbon is incorporated ought in the first instance to be green. Soon after the discovery of fluorescence, Dr. W. A. Miller pointed to the lime light as an illustration of exalted refrangibility. Direct experiments have since entirely confirmed the view expressed at page 210 of his work on *Chemistry*, published in 1855.

going experiment reach the retina at all?" The answer is that the rays were in part transmitted to the retina, and in part absorbed by the humors. Experiments on the eye of an ox showed that the proportion of obscure rays which reached the retina amounted to 18 per cent. of the total radiation, while the luminous emission from the electric light amounts to no more than 10 per cent. of the same total. Were the purely luminous rays of the electric lamp converged by our mirror to a focus, there can be no doubt as to the fate of a retina placed there. Its ruin would be inevitable; and yet this would be accomplished by an amount of wave motion but little more than half of that which the retina bears without being conscious of it at the focus of invisible rays.

This subject will repay a moment's further attention. At a common distance of a foot the visible radiation of the electric light is 800 times the light of a candle. At the same distance, that portion of the radiation of the electric light which reaches the retina but fails to excite vision is about 1,500 times the luminous radiation of the candle.* But a candle on a clear night can readily be seen at a distance of a mile, its light at this distance being less than one 20,000,000th of its light at the distance of a foot. Hence, to make the former equal in power to the non-luminous radiation received from the electric light at a foot distance, its intensity would have to be multiplied by $1,500 \times 20,000,000$, or by 30,000,000,000. Thus the thirty thousand millionth part of the radiation from the electric light, received unconsciously by the retina at the distance of a foot, would, if slightly changed in character, be amply sufficient to provoke vision. Nothing could more forcibly illustrate that special relationship supposed by Melloni and others to subsist between the optic nerve and the oscillating periods of luminous bodies. Like a musical string, the optic nerve responds to the waves with which it is in consonance, while it refuses to be excited by others of almost infinitely greater energy, whose periods of recurrence are not in unison with its own.

X.—PERSISTENCE OF RAYS.

At an early part of this lecture it was affirmed that when a platinum wire was gradually raised to a state of high incandescence, new rays were constantly added, while the intensity of the old ones was increased. Thus in Dr. Draper's experiments the rise of temperature that *generated* the orange, yellow, green, and blue rays *augmented* the intensity of the red ones. What is true of the red is true of every other ray of the spectrum, visible and invisible. We cannot indeed *see* the augmentation of intensity in the region beyond the red, but we can measure it and express it numerically. With this view the following experiment was performed: A spiral of platinum wire was surrounded by a small glass globe to protect it from currents of air; through an orifice in the globe the rays could pass from the spiral and fall afterwards upon a thermo-electric pile. Placing in front of the orifice an opaque solution of iodine, the platinum was gradually raised from a low dark heat to the fullest incandescence, with the following results:

Appearance of spiral.	Energy of obscure radiation.	Appearance of spiral.	Energy of obscure radiation.
Dark	1	Full red	62
Dark, but hotter	3	Orange	89
Dark, but still hotter	5	Bright orange	144
Dark, but still hotter	10	Yellow	202
Feeble red	19	White	276
Dull red	25	Intense white	440
Red	37		

* It will be borne in mind that the heat which any ray, luminous or non-luminous, is competent to generate is the true measure of the energy of the ray.

Thus the augmentation of the electric current, which raises the wire from its primitive dark condition to an intense white heat, exalts at the same time the energy of the obscure radiation, until at the end it is fully 440 times what it was at the beginning.

What has been here proved true of the totality of the ultra-red rays is true for each of them singly. Placing our linear thermo-electric pile in any part of the ultra-red spectrum, it may be proved that a ray once emitted continues to be emitted with increased energy as the temperature is augmented. The platinum spiral so often referred to being raised to whiteness by an electric current, a brilliant spectrum was formed from its light. A linear thermo-electric pile was placed in the region of obscure rays beyond the red, and by diminishing the current the spiral was reduced to a low temperature. It was then caused to pass through various degrees of darkness and incandescence, with the following results:

Appearance of spiral.	Energy of obscure rays.	Appearance of spiral.	Energy of obscure rays.
Dark	1	Full red	27
Dark	6	Orange	60
Faint red	10	Yellow	93
Dull red	13	Full white	122
Red	18		

Here, as in the former case, the dark and bright radiation reached their maximum together; as the one augmented the other augmented, until at last the energy of the obscure rays of the particular refrangibility here chosen became 122 times what it was at first. To reach a white heat the wire has to pass through all the stages of invisible radiation, and in its most brilliant condition it still embraces, in an intensified form, the rays of all those stages.

And thus it is with all other kinds of matter, as far as they have hitherto been examined. Coke, whether brought to a white heat by the electric current, or by the oxyhydrogen jet, pours out invisible rays with augmented energy as its light is increased. The same is true of lime, bricks, and other substances. It is true of all metals which are capable of being heated to incandescence. It also holds good for phosphorus burning in oxygen. Every gush of dazzling light has associated with it a gush of invisible radiant heat, which far transcends the light in energy. This condition of things applies to all bodies capable of being raised to a white heat, either in the solid or the molten condition. It would doubtless also apply to the luminous fogs formed by the condensation of incandescent vapors. In such cases, when the curve representing the radiant energy of the body is constructed, the obscure radiation towers upwards like a mountain, the luminous radiation resembling a mere spur at its base.

What, then, is the real origin of the luminous radiation? We find it appearing when the radiating body has attained a certain temperature; or, in other words, when the vibrating atoms of the body have attained a certain width of swing. In solid and molten bodies a certain amplitude cannot be surpassed without the introduction of periods of vibration, which provoke the sense of vision. If permitted to speculate, one might ask, are not these more rapid vibrations the product of the slower? Is it not really the mutual action of the atoms, when they swing through very wide spaces, and thus encroach upon each other, that causes them to tremble in quicker periods? If so, it matters not by what agency the large swinging space is obtained; we shall have light-giving vibrations associated with it. It matters not whether the large amplitudes are produced by the strokes of a hammer, or by the blows of the molecules of a non-luminous gas, such as the air at some height above a gas-flame; or by the shock of the ether particles when transmitting radiant heat. The result in all cases will be incandescence. Thus the invisible waves of our filtered electric beam, with which

incandescence has been produced, may be regarded as generating synchronous vibrations in the platinum on which they impinge; but once these vibrations attain a certain amplitude, the mutual jostling of the atoms would produce quicker tremors, and the light-giving waves would follow as the necessary progeny of the heat-giving vibrations. From the very brightness of the light of some of the fixed stars we may infer the intensity of the dark radiation, which is the precursor and inseparable associate of their luminous rays.

XI.—ABSORPTION OF RADIANT HEAT BY VAPORS AND ODORS.

We commenced the demonstrations brought forward in this lecture by experiments on permanent gases, and we have now to turn our attention to the vapors of volatile liquids. Here, as in the case of the gases, vast differences have been proved to exist between various kinds of molecules, as regards their power of intercepting the calorific waves. While some vapors allow the waves a comparatively free passage, in other cases the minutest bubble of vapor, introduced into the tube already employed for gases, causes a deflection of the magnetic needle. Assuming the absorption effected by air at a pressure of one atmosphere to be unity, the following are the absorptions effected by a series of vapors at a pressure of $\frac{1}{60}$th of an atmosphere:

Name of vapor.	Absorption.	Name of vapor.	Absorption.
Bisulphide of carbon	47	Sulphuric ether	440
Iodide of methyl	115	Formic ether	548
Benzol	136	Acetic ether	612
Amylene	321		

Bisulphide of carbon is the most transparent vapor in this list, and acetic ether the most opaque; $\frac{1}{60}$th of an atmosphere of the former, however, produces 47 times the effect of a whole atmosphere of air, while $\frac{1}{60}$th of an atmosphere of the latter produces 612 times the effect of a whole atmosphere of air. Reducing dry air to the pressure of the acetic ether here employed, and comparing them then together, the quantity of wave motion intercepted by the latter would be many thousand times that intercepted by the air.

Any one of these vapors discharged in the free atmosphere, in front of a body emitting obscure rays, intercepts more or less of the radiation. A similar effect is produced by perfumes diffused in the air, though their attenuations is known to be almost infinite. Carrying, for example, a current of dry air over bibulous paper moistened by patchouli, the scent taken up by the current absorbs 30 times the quantity of heat intercepted by the air which carries it; and yet patchouli acts more feebly on radiant heat than any other perfume yet examined. Here follow the results obtained with various essential oils, the odor, in each case, being carried by a current of dry air into the tube already employed for gases and vapors:

Name of perfume.	Absorption.	Name of perfume.	Absorption.
Patchouli	30	Portugal	67
Sandal wood	32	Thyme	68
Geranium	33	Rosemary	74
Oil of cloves	34	Oil of laurel	80
Otto of roses	37	Camomile flowers	87
Bergamot	44	Cassia	109
Neroli	47	Spikenard	355
Lavender	60	Aniseed	372
Lemon	65		

Thus the absorption by a tube full of dry air being one, that of the odor of patchouli diffused in it is 30, that of lavender 60, that of rosemary 74, while that of aniseed amounts to 372. It would be idle to speculate on the quantities of matter concerned in these actions.

XII.—AQUEOUS VAPOR IN RELATION TO TERRESTRIAL TEMPERATURES.

We are now fully prepared for a result which, without such preparation, might appear incredible. Water is, to some extent, a volatile body, and our atmosphere, resting as it does upon the surface of the ocean, receives from it a continuous supply of aqueous vapor. It would be an error to confound clouds of fog or any visible mist with the vapor of water; this vapor is a perfectly impalpable gas, diffused, even on the clearest days, throughout the atmosphere. Compared with the great body of the air, the aqueous vapor it contains is of almost infinitesimal amount, 99½ out of every 100 parts of the atmosphere being composed of oxygen and nitrogen. In the absence of experiment we should never think of ascribing to this scant and varying constituent any important influence on terrestrial radiation; and yet its influence is far more potent than that of the great body of the air. To say that on a day of average humidity in England the atmospheric vapor exerts 100 times the action of the air itself, would certainly be an understatement of the fact. The peculiar qualities of this vapor, and the circumstance that at ordinary temperatures it is very near its point of condensation, render the results which it yields in the apparatus already described less than the truth; and I am not prepared to say that the absorption by this substance is not 200 times that of the air in which it is diffused. Comparing a single molecule of aqueous vapor with an atom of either of the main constituents of our atmosphere, I am not prepared to say how many thousand times the action of the former exceeds that of the latter.

These large numbers depend in part upon the extreme feebleness of the air; the power of aqueous vapor seems vast, because that of the air with which it is compared is infinitesimal. Absolutely considered, however, this substance exercises a very potent action. Probably a column of ordinary air 10 feet long would intercept from 10 to 15 per cent. of the heat radiated from an obscure source, and I think it certain that the larger of these numbers fails to express the absorption of the terrestrial rays effected within 10 feet of the earth's surface. This is of the utmost consequence to the life of the world. Imagine the superficial molecules of the earth trembling with the motion of heat, and imparting it to the surrounding ether; this motion would be carried rapidly away and lost forever to our planet if the waves of ether had nothing but the air to contend with in their outward course. But the aqueous vapor takes up the motion of the ethereal waves and becomes thereby heated, thus wrapping the earth like a warm garment, and protecting its surface from the deadly chill which it would otherwise sustain. Various philosophers have speculated on the influence of an atmospheric envelope. De Saussure, Fourier, M. Pouillet, and Mr. Hopkins have, one and all, enriched scientific literature with contributions on this subject, but the considerations which these eminent men have applied to atmospheric air have now to be transferred to aqueous vapor.

The observations of meteorologists furnish important, though hitherto unconscious, evidence of the influence of this agent. Wherever the air is dry we are liable to daily extremes of temperature. By day, in such places, the sun's heat reaches the earth unimpeded and renders the maximum high; by night, on the other hand, the earth's heat escapes unhindered into space and renders the minimum low. Hence the difference between the maximum and minimum is greatest where the air is driest. In the plains of India, on the heights of the Himalaya, in central Asia, in Australia, wherever drought reigns we have the heat of day forcibly contrasted with the chill of night. In the Sahara itself, when the sun's

rays cease to impinge on the burning soil, the temperature runs rapidly down to freezing, because there is no vapor overhead to check the calorific drain. And here another instance might be added to the numbers already known, in which nature tends, as it were, to check her own excess. By nocturnal refrigeration the aqueous vapor of the air is condensed to water on the surface of the earth, and, as only the superficial portions radiate, the act of condensation makes water the radiating body. Now experiment proves that to the rays emitted by water, aqueous vapor is especially opaque. Hence the very act of condensation, consequent on terrestrial cooling, becomes a safeguard to the earth, imparting to its radiation that particular character which renders it most liable to be prevented from escaping into space.

It might, however, be urged that, inasmuch as we derive all our heat from the sun, the self-same covering which protects the earth from chill must also shut out the solar radiation. This is partially true, but only partially; the sun's rays are different in quality from the earth's rays, and it does not at all follow that the substance which absorbs the one must necessarily absorb the other. Through a layer of water, for example, one-tenth of an inch in thickness, the sun's rays are transmitted with comparative freedom; but through a layer half this thickness, as Melloni has proved, no single ray from the warmed earth could pass. In like manner, the sun's rays pass with comparative freedom through the aqueous vapor of the air, the absorbing power of this substance being mainly exerted upon the heat that endeavors to escape from the earth. In consequence of this differential action upon solar and terrestrial heat, the mean temperature of our planet is higher than is due to its distance from the sun.

XIII.—LIQUIDS AND THEIR VAPORS IN RELATION TO RADIANT HEAT.

The deportment here assigned to atmospheric vapor has been established by direct experiments on air taken from the streets and parks of London, from the downs of Epsom, from the hills and sea-beach of the Isle of Wight, and also by experiments on air in the first instance dried and afterwards rendered artificially humid by pure distilled water. It has also been established in the following way: Ten volatile liquids were taken at random, and the power of these liquids, at a common thickness, to intercept the waves of heat was carefully determined. The vapors of the liquids were next taken, in quantities proportional to the quantities of liquid, and the power of the vapors to intercept the waves of heat was also determined. Commencing with the substance which exerted the least absorptive power, and proceeding upward to the most energetic, the following order of absorption was observed:

Liquids.	*Vapors.*
Bisulphide of carbon.	Bisulphide of carbon.
Chloroform.	Chloroform.
Iodide of methyl.	Iodide of methyl.
Iodide of ethyl.	Iodide of ethyl.
Benzol.	Benzol.
Amylene.	Amylene.
Sulphuric ether.	Sulphuric ether.
Acetic ether.	Acetic ether.
Formic ether.	Formic ether.
Alcohol.	Alcohol.
Water.	

We here find the order of absorption in both cases to be the same. We have liberated the molecules from the bonds which trammel them more or less in a liquid condition; but this change in their state of aggregation does not change their relative powers of absorption. Nothing could more clearly prove that the

act of absorption depends upon the individual molecule, which equally asserts its power in the liquid and the gaseous state. We may assuredly conclude from the above table that the position of a vapor is determined by that of its liquid. Now, at the very foot of the list of liquids stands water, signalizing itself above all others by its enormous power of absorption; and from this fact, even if no direct experiment on the vapor of water had ever been made, we should be entitled to rank that vapor as the most powerful absorber of radiant heat hitherto discovered. It has been proved by experiment that a shell of air two inches in thickness surrounding our planet, and saturated with the vapor of sulphuric ether, would intercept 35 per cent. of the earth's radiation; and though the quantity of aqueous vapor necessary to saturate air is much less than the amount of sulphuric ether vapor which it can sustain, it is still extremely probable that the estimate already made of the action of atmospheric vapor within 10 feet of the earth's surface is altogether under the mark, and that we are indebted to this wonderful substance, to an extent not accurately determined, but certainly far beyond what has hitherto been imagined, for the temperature now existing at the surface of the globe.

XIV.—RECIPROCITY OF RADIATION AND ABSORPTION.

Throughout the reflections which have hitherto occupied us the image before the mind has been that of a radiant source generating calorific waves, which, on passing among the scattered molecules of a gas or vapor, were intercepted by those molecules in various degrees. In all cases it was the transference of motion from the ether to the comparatively quiescent molecules of the gas or vapor. We have now to change the form of our conception, and to figure these molecules not as absorbers but as radiators—not as the recipients but as the originators of wave motion; that is to say, we must figure them vibrating and generating in the surrounding ether undulations which speed through it with the velocity of light. Our object now is to inquire whether the act of chemical combination, which proves so potent as regards the phenomena of absorption, does not also manifest its power in the phenomena of radiation. For the examination of this question it is necessary, in the first place, to heat our gases and vapors to the same temperature, and then examine their power of discharging the motion thus imparted to them upon the ether in which they swing.

A heated copper ball was placed above a ring gas-burner possessing a great number of small apertures, the burner being connected by a tube with vessels containing the various gases to be examined. By a gentle pressure the gases were forced through the orifices of the burner against the copper ball, where each of them, being heated, rose in an ascending column. A thermo-electric pile, entirely screened off from the hot ball, was exposed to the radiation of the warm gas, and the deflection of a magnetic needle connected with the pile declared the energy of the radiation.

By this mode of experiment it was proved that the self-same molecular arrangement which renders a gas a powerful absorber renders it in the same degree a powerful radiator—that the atom or molecule which is competent to intercept the calorific waves is, in the same degree, competent to generate them. Thus, while the atoms of elementary gases proved themselves unable to emit any sensible amount of radiant heat, the molecules of compound gases were shown to be capable of powerfully disturbing the surrounding ether. By special modes of experiment the same was proved to hold good for the vapors of volatile liquids, the radiative power of every vapor being found proportional to its absorptive power. These experiments were based upon the fact that atoms, such, for example, as those of air, which glide through the ether without sensible resistance, cannot thus glide among the molecules of another gas. When mixed with such molecules, the heated atoms communicate their motion to the molecules by direct col-

lision, and if these be of a complex chemical character they instantly disturb the ether which surrounds them and thus lose their heat. Hence the motion possessed in the first instance by the atoms, and which the atoms are incompetent to discharge directly upon the ether, may, by the intervention of more complex molecules, be thus discharged. Suppose, then, a small quantity of any vapor to be introduced into an exhausted tube, and air to be subsequently allowed to rush in and fill the tube. By its impact against the sides of the tube the air is heated; the motion of heat is instantly imparted, by collision, to the molecules of the vapor, and they in their turn impart it to the ether, or, in other words, reduce it to the radiant form. By this process, which has been called dynamic radiation, the radiative power of both vapors and gases has been determined, and the reciprocity of their radiation and absorption proved.* In the excellent researches of Leslie, De la Provostaye, and Desains, and Mr. Balfour Stewart, the reciprocity of radiation and absorption in the case of solid bodies has been variously illustrated; while the labors, theoretical and experimental, of Kirchoff have given this subject a wonderful expansion, and enriched it by applications of the highest kind. To their results are now to be added the foregoing, whereby a vast class of bodies hitherto thought inaccessible to experiment are proved to exhibit the duality of radiation and absorption, the influence on both of chemical combination being exhibited in the most decisive and extraordinary way.

XV.—INFLUENCE OF VIBRATING PERIOD AND MOLECULAR FORM.—PHYSICAL ANALYSIS OF THE HUMAN BREATH.

In the foregoing experiments with gases and vapors we have employed throughout invisible rays. Some of these bodies are so impervious that in lengths of a few feet only they intercept every ray as effectually as a layer of pitch would do. The substances, however, which show themselves thus opaque to radiant heat are perfectly transparent to light. Now the rays of light differ from those of invisible heat only in point of period, the former failing to affect the retina because their periods of recurrence are too slow. Hence, in some way or other, the transparency of our gases and vapors depends upon the periods of the waves which impinge upon them. What is the nature of this dependence? The admirable researches of Kirchoff help us to an answer. The atoms and molecules of every gas have certain definite rates of oscillation, and those waves of ether are most copiously absorbed whose periods of recurrence synchronize with the periods of the molecules among which they pass. Thus, when we find the invisible rays absorbed and the visible ones transmitted by a layer of gas, we conclude that the oscillating periods of the gaseous molecules coincide with those of the invisible, and not with those of the visible spectrum.

It requires some discipline of the imagination to form a clear picture of this process. Such a picture is, however, possible. When the waves of ether impinge upon molecules whose periods of vibration coincide with the recurrence of the undulations, the timed strokes of the waves cause the motion of the molecules to accumulate, as a heavy pendulum is set in motion by well-timed puffs of breath. Thousands of millions of shocks are received every second from the calorific waves, and it is not difficult to see that every wave, arriving just in time to repeat the action of its predecessor, the molecules must finally be caused to swing through wider spaces than if the arrivals were not so timed. In fact, it is not difficult to see that an assemblage of molecules, operated upon by contending waves, might remain practically quiescent, and this is actually the case when the waves of the visible spectrum pass through a transparent gas or vapor. There is here no sensible transference of motion from the ether to the molecules; in other words, there is no sensible absorption.

* When heated air imparts its motion to another gas or vapor, the transference of heat is accompanied by a change of vibrating period. The dynamic radiation of vapors is rendered possible by the transmutation of vibrations.

One striking example of the influence of period may be here recorded. Carbonic acid gas is one of the feeblest of absorbers of the radiant heat emitted by solid sources. It is, for example, extremely transparent to the rays emitted by the heated copper plate already referred to. There are, however, certain rays, comparatively few in number, emitted by the copper, to which the carbonic acid is impervious; and could we obtain a source of heat emitting such rays only, we should find carbonic acid more opaque than any other gas to the radiation from that source. Such a source is actually found in the flame of carbonic oxide, where hot carbonic acid constitutes the main radiating body. Of the rays emitted by our heated plate of copper, olefiant gas absorbs ten times the quantity absorbed by carbonic acid; of the rays emitted by a carbonic oxide flame, carbonic acid absorbs twice as much as olefiant gas. This wonderful change in the power of the former as an absorber is simply due to the fact that the periods of the hot and cold carbonic acid are identical, and the waves from the flame freely transfer their motion to the molecules which synchronize with them. Thus it is that the tenth of an atmosphere of carbonic acid, enclosed in a tube four feet long, absorbs 60 per cent. of the radiation from a carbonic oxide flame, while one-thirtieth of an atmosphere absorbs 48 per cent. of the heat from the same origin.

In fact the presence of the minutest quantity of carbonic acid may be detected by its action on the rays from the carbonic oxide flame. Carrying, for example, the dried human breath into a tube four feet long, the absorption there effected by the carbonic acid of the breath amounts to 50 per cent. of the entire radiation. Radiant heat may indeed be employed as a means of determining practically the amount of carbonic acid expired from the lungs. My assistant, Mr. Barrett, has, at my request, made this determination. The absorption produced by the breath, freed from its moisture, but retaining its carbonic acid, was first determined. Carbonic acid, artificially prepared, was then mixed with dry air in such proportions that the action of the mixture upon the rays of heat was the same as that of the dried breath. The percentage of the former being known, immediately gave that of the latter. The same breath, analyzed chemically by Dr. Frankland, and physically by Mr. Barrett, gave the following results:

Percentage of carbonic acid in the human breath.

Chemical analysis.	Physical analysis.
4.66	4.56
5.33	5.22

It is thus proved that in the quantity of ethereal motion which it is competent to take up, we have a practical measure of the carbonic acid of the breath, and hence of the combustion going on in the human lungs.

Still this question of period, though of the utmost importance, is not competent to account for the whole of the observed facts. The ether, as far as we know, accepts vibrations of all periods with the same readiness. To it the oscillations of an atom of oxygen are just as acceptable as those of a molecule of olefiant gas; that the vibrating oxygen then stands so far below the olefiant gas in radiant power must be referred not to period, but to some other peculiarity of the respective molecules. The atomic group which constitutes the molecule of olefiant gas produces many thousand times the disturbance caused by the oxygen because the group is able to lay a vastly more powerful hold upon the ether than the single atoms can. The cavities and indentations of a molecule composed of spherical atoms may be one cause of this augmented hold. Another, and possibly very potent one, may be, that the ether itself, condensed and entangled among the constituent atoms of a compound, virtually increases the magnitude of the group, and hence augments the disturbance. Whatever may be the fate of these attempts to visualize the physics of the process, it will still remain true, that to account for the phenomena of radiation and absorption we must

take into consideration the shape, size, and complexity of the molecules by which the ether is disturbed.

XVI.—SUMMARY AND CONCLUSION.

Let us now cast a momentary glance over the ground that we have left behind. The general nature of light and heat was first briefly described: the compounding of matter from elementary atoms and the influence of the act of combination on radiation and absorption were considered and experimentally illustrated. Through the transparent elementary gases radiant heat was found to pass as through a vacuum, while many of the compound gases presented almost impassable obstacles to the calorific waves. This deportment of the simple gases directed our attention to other elementary bodies, the examination of which led to the discovery that the element iodine, dissolved in bisulphide of carbon, possesses the power of detaching, with extraordinary sharpness, the light of the spectrum from its heat, intercepting all luminous rays up to the extreme red, and permitting the calorific rays beyond the red to pass freely through it. This substance was then employed to filter the beams of the electric light, and to form foci of invisible rays so intense as to produce almost all the effects obtainable in an ordinary fire. Combustible bodies were burnt and refractory ones were raised to a white heat by the concentrated invisible rays. Thus, by exalting their refrangibility, the invisible rays of the electric light were rendered visible, and all the colors of the solar spectrum were extracted from utter darkness. The extreme richness of the electric light in invisible rays of low refrangibility was demonstrated, one-tenth only of its radiation consisting of luminous rays. The deadness of the optic nerve to those invisible rays was proved, and experiments were then added to show that the bright and the dark rays of a body raised gradually to intense incandescence are strengthened together; that to reach intense white heat intense dark heat must be generated. A sun could not be formed or a meteorite rendered luminous on any other conditions. The light-giving rays constitute only a small fraction of the total radiation, their unspeakable importance to us being due to the fact that their periods are attuned to the special requirements of the eye.

Among the vapors of volatile liquids vast differences were also found to exist as regards their power of absorption. We followed, moreover, various molecules from a state of liquid to a state of gas, and found, in both states of aggregation, the power of the individual molecules equally asserted. The position of a vapor as an absorber of radiant heat was proved to be determined by that of the liquid from which it is derived. Reversing our conceptions, and regarding the molecules of gases and vapors not as the recipients, but as the originators of wave motion—not as absorbers, but as radiators—it was proved that the powers of absorption and radiation went hand in hand, the self-same chemical act which rendered a body competent to intercept the waves of ether rendering it competent in the same degree to generate them. Perfumes were next subjected to examination, and, notwithstanding their extraordinary tenuity, were found vastly superior, in point of absorptive power, to the body of the air in which they were diffused. We were led thus slowly up to the examination of the most widely diffused and most important of all vapors—the aqueous vapor of our atmosphere—and we find in it a potent absorber of the purely calorific rays. The power of this substance to influence climate, and its general influence on the temperature of the earth, were then briefly dwelt upon. A cobweb spread above a blossom is sufficient to protect it from nightly chill; and thus the aqueous vapor of our air, attenuated as it is, checks the drain of terrestrial heat and saves the surface of our planet from the refrigeration which would assuredly accrue were no such substance interposed between it and the voids of space. We considered the influence of vibrating period and molecular form on absorption and radiation,

and finally deduced from its action upon radiant heat the exact amount of carbonic acid expired by the human lungs.

Thus, in brief outline, have I placed before you some of the results of recent inquiries in the domain of radiation, and my aim throughout has been to raise in your minds distinct physical images of the various processes involved in our researches. It is thought by some that natural science has a deadening influence on the imagination, and a doubt might fairly be raised as to the value of any study which would necessarily have this effect. But the experience of the last hour must, I think, have convinced you that the study of natural science goes hand in hand with the culture of the imagination. Throughout the greater part of this discourse we have been sustained by this faculty; we have been picturing atoms and molecules and vibrations and waves which eye has never seen nor ear heard, and which can only be discerned by the exercise of imagination. This, in fact, is the faculty which enables us to transcend the boundaries of sense, and connect the phenomena of our visible world with those of an invisible one. Without imagination we never could have risen to the conceptions which have occupied us here to-day; and in proportion to your power of exercising this faculty aright, and of associating definite mental images with the terms employed, will be the pleasure and the profit which you will derive from this lecture. The outward facts of nature are insufficient to satisfy the mind. We cannot be content with knowing that the light and heat of the sun illuminate and warm the world. We are led irresistibly to enquire what is light and what is heat; and this question leads us at once out of the region of sense into that of imagination.

Thus pondering, and asking, and striving to supplement that which is felt and seen, but which is incomplete, by something unfelt and unseen which is necessary to its completeness, men of genius have in part discerned, not only the nature of light and heat, but also, through them, the general relationship of natural phenomena. The power of nature is the power of motion, of which all its phenomena are but special forms. It manifests itself in tangible and in intangible matter, being incessantly transferred from the one to the other, and incessantly transformed by the change. It is as real in the waves of the ether as in the waves of the sea, the latter being, in fact, nothing more than the heaped-up motion of the former, for it is the calorific waves emitted by the sun which heat our air, produce our winds, and hence agitate our ocean; and whether they break in foam upon the shore, or rub silently against the ocean's bed, or subside by the mutual friction of their own parts, the sea-waves finally resolve themselves into waves of ether, and thus regenerate the motion from which their temporary existence was derived. This connection is typical. Nature is not an aggregate of independent parts, but an organic whole. If you open a piano and sing into it a certain string will respond. Change the pitch of your voice; the first string ceases to vibrate, but another replies. Change again the pitch; the first two strings are silent, while another resounds. Now, in altering the pitch you simply change the form of the motion communicated by your vocal chords to the air, one string responding to one form and another to another. And thus is sentient man sung unto by nature, while the optic, the auditory, and other nerves of the human body are so many strings differently tuned and responsive to different forms of the universal power.

SYNTHETIC EXPERIMENTS RELATIVE TO METEORITES—APPROXIMATIONS TO WHICH THESE EXPERIMENTS LEAD.*

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[*Translated for the Smithsonian Institution.*]

The study of meteorites touches on several fundamental questions of the physical history of the universe. Aside from the importance which these bodies present in a purely astronomical point of view, they are furthermore of interest to geology from their constitution itself, and this under a two-fold aspect. On the one hand, they are the only specimens of extra-terrestrial or cosmical bodies with which it is possible for us to have actual contact; or which can afford us any ideas respecting the constitution of the bodies scattered through the celestial spaces. On the other hand, the more thorough our study of them the better shall we recognize the bearing which they may have on sundry branches of knowledge, and particularly the history of our globe, as will be seen further on. Thus it is that meteorites constitute an essential as well as new chapter in geology; and notwithstanding the little attention hitherto accorded to their study by geologists, it cannot but be considered, on the grounds just stated, as meriting a place in the pages of the *Annales des Mines.*

In a recently published report on the progress of a part of geology, which may be called *experimental geology*,† we had occasion to explain how far experiment had been made instrumental in solving the questions which relate to the origin of meteorites and the mode of their formation; this chapter it has been thought proper to reproduce here, with some developments, a portion of which had found a place in previous publications. The title sufficiently indicates the propriety of reducing the historical and descriptive part to a very succinct exposition.

CHAPTER I.

EXTRA-TERRESTRIAL ORIGIN OF METEORITES.—PHENOMENA WHICH ACCOMPANY THEIR FALL.

It is a long time since any doubt could be entertained that among the substances which fall from the atmosphere to the surface of the globe, there are some whose origin is incontestably foreign to the planet which we inhabit. Their descent makes itself known by a considerable production of light and sound which accompanies it, by the almost horizontal trajectory which they describe, and by the excessive velocity of the *bolides* which embody the substances in question.

Several recent falls, which have been studied with care, have enabled us to determine with more precision the circumstances which attend the arrival

* *Annales des Mines, &c., Paris*, 1868.

† *Rapport sur les progrès de la géologie expérimentale. Imprimerie impériale*, 1867.

of these masses on the earth. That these circumstances are constantly and identically reproduced, is extremely remarkable. The fall of meteorites is always accompanied by an incandescence sufficiently vivid to give to night an appearance of day, and to be perfectly perceptible even at noon-day. In consequence of this vivacity of their light, the arrival of meteorites in our atmosphere may be seen at very great distances; the fall at Orgueil (Tarn-et-Garonne.) of the 14th May 1864, was observed as far off as Gisors (Eure,) a distance of more than 500 kilometers,* (310½ miles.)

The light in question is, moreover, of very transient duration. It is thought to be produced at the moment when the asteroid enters our atmosphere, and therefore at a great height, which, in the case of Orgueil, for example, has been computed at 65 kilometers, (40 miles.) It is owing to this incandescence that the trajectory of meteorites, which is in general but little inclined to the horizon, is susceptible of being observed. A trajectory of this nature was particularly verified for the bolide of Orgueil just cited: proceeding from the west towards the east, this bolide was followed from Santander and other points of the coast of Spain to the place of its fall. The incandescence allows, moreover, of an appreciation of the velocity of the bolides, a velocity which has nothing analogous on the earth, and which can only be compared to that of the planets revolving in their orbits. This single circumstance would suffice to prove the cosmic origin of meteorites. The meteorite of Orgueil appeared to traverse about 20 kilometers (12½ miles) per second; while in other cases velocities have been observed which could not be estimated at less than 30 kilometers, (18½ miles.)

The appearance of the bolide is constantly accompanied by a trail of vapors, which are themselves not destitute of a certain effulgence. No instance of the fall of a meteorite has occurred without being preceded by an explosion and sometimes by several explosions. The noise of the explosion has been compared either to that of thunder or to that of cannon, according to the distance of the observers. It makes itself heard over a vast extent of country; sometimes at a distance of more than 100 kilometers in circuit, as in the fall at Orgeuil. If we reflect that it is produced in regions where the air, highly rarefied, lends itself very imperfectly to the propagation of sound, we shall readily be convinced that its intensity must be such as to surpass all else that is known to us. After the explosion a whizzing sound is heard, owing to the rapid passage of detached pieces in the air, which the Chinese compare to the noise made by the wings of wild geese, or to that of a cloth which is torn. It should be added that these phenomena have been observed not only in widely distant regions of the globe, but at all seasons, at all hours, and often when the sky is serene and cloudless and the air calm. Tempests, water-spouts, therefore, have no agency here.

To obviate an objection which naturally presents itself to the mind, in relation to the velocity of these bodies, attention must be drawn to an essential distinction. The enormous velocity proper to the luminous body or bolide which is seen cleaving the atmosphere contrasts with that, incomparably more feeble, which the fragments possess at the moment of their arrival on the earth. The bolide moves like a body *launched* with a great initial velocity; on the contrary the fragments which reach us in the sequel of the explosion appear, in general, to possess only a velocity comparable to that which would correspond to their *descent*, moderated, besides, by the resistance of the air. It is to be added that, as the bolides move in all directions, their relative velocity, all else being equal, must necessarily vary according to the course of the trajectory with regard to the direction of the earth's rotation and motion in its orbit.

The stones of any one fall are more or less numerous, and are always burning hot on the surface at the moment of their arrival, without, however, having preserved their incandescence. At Orgueil stones fell upon 60 points, comprised

* A kilometre is 62 hundredths of a mile.

within an oval periphery, of which the greater axis was 20 kilometers in length. The fall at Stannern, in Moravia, yielded several hundreds of specimens, and that of Aigle about 3,000; here, as at Orgueil, the space covered by the stones was oval, and was 12 kilometers in length. A recent fall observed at Knyahinia, in Hungary, was scarcely less numerous than that of Aigle. Frequently stones of a certain volume penetrate deep into the soil; for example, one of those collected at Aumale had buried itself several decimeters in a block of compact and resistant limestone. Hence a great number of meteorites may remain buried and undiscoverable.

The phenomena of light and sound with which the fall of meteorites is attended being of such imposing magnitude, it is not without surprise that we observe the absence of any voluminous mass among the stones which have fallen. The largest specimen collected at Orgueil weighed two kilograms; none of those of Aigle exceeded nine. The weight of 50 kilograms* is not often surpassed; it is only exceptionally that some stones of from 200 to 300 kilograms can be cited. We may add that the weight of the fragments amounts sometimes to but a few grams. In the case of iron meteorites, the weight is often more considerable; there have been found of these some weighing from 700 to 800 kilograms, like that of Charcas recently brought to the museum; and a specimen has been found in Brazil having a weight estimated at 7,000 kilograms; but even this last represents but a volume equal to one cubic meter. Meteorites, therefore, might be regarded as, in some sort, minute planetary débris; as it were, *cosmic dust.*

It is not impossible, however, that the fragments which reach the surface of our globe represent but a small part of the meteoric mass; the latter may be supposed to pass from our atmosphere and continue its course, abandoning only some small portions whose velocity has been weakened in consequence of the explosion. The fall at Orgueil would furnish an argument in favor of this hypothesis.†

What is first remarked, on examining meteoric stones, is a black crust which covers the whole surface.‡ This crust is, in general, of a dull appearance; but in some aluminous and particularly fusible meteorites it is of a glittering aspect, so as to resemble a varnish. Its thickness is less than one millimetre, and it is plainly owing to a superficial fusion which the stone has undergone for a very short time, being the result of the incandescence produced on its entering the atmosphere. The crust may be artificially reproduced by submitting fragments of the meteorite to the flame of the blow-pipe.

Lightning produces on the rocks of the earth a varnish which is not without analogy to that of meteorites; it occasions in effect on certain rocks, particularly towards the summit of mountains, the formation of little drops or of a glaze, to which De Saussure first called attention. It was on account of this resemblance that the savants, to whom were submitted the stones which fell at Lucé (Sarthe,) in 1768, expressed the opinion that they were only terrestrial stones vitrified by lightning The crust of meteorites presents little wrinkles, the direction of which indicates the course followed by each of the fragments. This course is still more plainly indicated by the arrangement of certain small prominences which the varnish has produced by trickling to the after part of each stone. The form of the pieces detached from the meteorites is essentially fragmentary; they are irregular polyhedrons, whose angles and edges have been blunted by the simultaneous action of heat and friction.

From all the facts above enumerated, it evidently results that the meteorites are representatives of extra-terrestrial or cosmic bodies. The first idea which

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* A kilogram is 2.2 pounds.

† *Nouvelles Archives du Muséum*, t. iii, 1866.

‡ The meteorite which fell, 9th June, 1867, at Tadjera, in Algeria, presents a very remarkable exception through the absence of a crust. This difference corresponds to a less degree of fusibility than that of meteorites of the common type. (*Comptes Rendus*, t. lxvi, p. 513, 1868.)

presented itself was to seek their origin in the planet nearest to us. It was thus, as will be remembered, that Laplace and Berzelius regarded them as bodies ejected from lunar volcanoes. But the hypothesis most generally adopted is that which Chladni ventured to enunciate in 1794; according to this, the stones that descend from the skies are asteroids, which, entering within the sphere of the earth's attraction, are precipitated to its surface. These asteroids, moreover, need not pertain to our own planetary system; there is nothing to prove that they do not proceed from other regions of space.

The number of the known falls of meteorites is not so considerable as might be inferred from the great number of bolides which have been observed and which daily come to light. Those which have been well authenticated, and the stones of which have been collected, do not, to our knowledge, amount to 1,000. In this sort of verification we necessarily do not take account of a number of falls, otherwise quite considerable, which have left us neither trace nor memento.

But however incomplete the statistics of these falls, it is well to note how they are distributed in point of time. From monthly statements it would appear that the two months which are remarkable for showers of shooting stars have no pre-eminence as regards the number of the descents of bolides. In the horary distribution the variations are more marked; the falls seem to be more frequent by day than by night, as is shown by the facts observed by MM. Alex. Herschel, De Haidinger, and Quetelet.

As regards the geographical apportionment of meteorites, they have been signalized in all parts of the globe. Nevertheless, this apportionment is far from being uniform; certain points seem distinguished for them. The abundance of ferruginous meteors in certain parts of America, north and south, in Mexico, the United States, and Chili, is well known. While some countries make no mention of falls of stones, or mention them very rarely, as Switzerland, other countries of the same surface, and which appear not better prepared for the verification of phenomena of this kind, have been often their theatre. Such are some of the regions of southern France, (Barbotan, Agen, Toulouse, Orgueil, Laissac, Alais, Juvinas,) the northern part of Italy and British India, the latter having witnessed not less than 34 since the end of the last century. During each of the two years 1863 and 1864, as well as in 1866, three falls of meteorites have been cited in Europe. If we assume that this part of the world has not been particularly favored, and remember that it represents sixteen-thousandths of the total surface of the globe, we should realize for that whole surface the number of 180 meteorites. If, by reason of the facility with which the phenomenon may pass unperceived, this number be raised three-fold, which is doubtless far from being an exaggeration, we find a total of from 600 to 700 for the annual number of falls.

It results from these falls of meteorites that, each year, the mass of the globe is augmented by a certain quantity, and, according to a principle of mechanics, this augmentation would necessarily have an influence on the velocity of the rotation of our planet. It has been sought to ascribe to this cause the secular acceleration of the mean movement of the moon; but that acceleration is very far from being completely explained by the phenomenon in question.* Under this point of view, the very slight increase of mass produced by the arrival of these extra-terrestrial bodies may, it would seem, be wholly neglected.

When we reflect on the number of meteorites which the earth receives from year to year, we are impelled to admit that numbers must have fallen likewise, in the vast periods of time during which the strata of the earth were formed, on land as well as in the basin of the ocean itself. Yet, often as the stratified formations have been explored, nothing analogous to the meteoric stones has ever been noticed. This remarkable fact may be, perhaps, explained, in accordance

* As M. Delaunay has recently demonstrated, (*Comptes Rendus*, t. lxi, p. 1023.)

with the result of experiments on which I entered some time ago, by the facility with which these stones disappear in consequence of their oxidation under the action of water and the disintegration which is its consequence.

CHAPTER II.

CONSTITUTION OF METEORITES.—§ 1. TYPES TO BE DISTINGUISHED.

If we examine meteorites as regards their constitution, it will be seen that some are formed of iron, evidently pure, while others consist of masses exclusively lapideous. Between these extreme types, specimens are found of a mixed nature, forming, as it were, a bond of union. Hence, it is convenient to adopt a single name; applicable to all the substances which reach us from the skies, to the iron as well as stone, and even to the pulverulent or gaseous substances which may have the same origin. Such a name is that of *meteorite;* while the name of *aerolite* should be rejected as designating exclusively stony substances.

We proceed to give a rapid review of the classification recently adopted for the collection of the museum. (*Comptes Rendus de l'Académie des Sciences*, t. lxv, p. 60, 1867.)

METEORITES OF THE FIRST GROUP, OR HOLOSIDEROUS.

Meteoric iron forms masses destitute of stony matter, and sometimes sufficiently pure to be susceptible of being immediately forged; it has even been employed in the fabrication of arms and utensils. No terrestrial mineral can, in this respect, be compared to it; native iron, it is true, has been found on the surface of the globe, but always under exceptional circumstances, when it appeared to proceed from reductions accidentally effected, either by combustible gases generated in volcanoes, or by the conflagration of coal-beds. This terrestrial iron, moreover, never presents the characters of meteoric iron.

This latter is characterized at once by its chemical composition, and by its structure. It is always associated with different metals, among which nickel is the most constant. It frequently contains a sulphate of iron (troïlite,) isolated under a kidney-shaped form, sometimes cylindroidal and engaged in graphite. We find, besides, a phosphate of iron and of nickel, containing magnesium, the existence of which has been demonstrated by Berzelius, and to which the name of *schreibersite* has been applied. Terrestrial iron has never this composition.

We will cite, as an example, the iron meteorite of Caille (*Alpes Maritimes*), the first analysis of which we owe to the Duke de Luynes, (*Annales des Mines*, 4th series, t. v, p. 161, 1844). He found it to be exclusively formed of iron and nickel, with imponderable traces of manganese and copper. The proportion of nickel rises, according to this analysis, to 17.37 per 100. The results at which M. Rivot has subsequently arrived in regard to other specimens of the same mass are sensibly different, this chemist having detected neither manganese nor copper, but having found cobalt and chrome. Such divergencies teach us how much the composition of these masses may vary, even in pieces with an identical aspect.*

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* *Annales des Mines*, 5th series, t. vi, p. 554, 1854. The following are the numbers he obtained:

Iron	92.7
Nickel	5.6
Chrome, cobalt, traces of silicium	0.9
Total	98.2

The author thinks that the silicium is contained in the mass in the state of a siliciuret.

The structure of ferruginous meteorites is among the most remarkable. In order to observe it, after having polished a surface of the bolide, we submit it to the action of an acid; we thus bring to view the figures called *Widmanstätten*, from the name of the savant who first mentioned them. In this way we ascertain that the body in question is at once crystalline and heterogeneous. An unassailable matter, in effect, soon appears in relief and transforms the surface, originally plane, into an actual stereotype plate, suitable for producing impressions. The substance which thus appears in relief is simply the multiple phosphuret of Berzelius. This phosphuret presents itself ordinarily in thin laminæ, the intervals of which remind us, by their fineness and their parallelism, of a series of strokes of the burin. The different laminæ, which thus traverse the meteoric iron, are generally directed parallel to the faces of the regular octahedron. This fact, easily to be verified in the iron meteorite discovered at Caille, is the more interesting as the terrestrial iron, which is produced in crystalline masses, presents a cubic arrangement. If we follow the direction *(orientation)* of the octahedrons, it will be recognized that, in many masses of iron, they present a parallelism, whence it results that they constitute in their *ensemble* a single crystal. The dimension, thus considerable, of these crystals contrasts with the structure observed in artificial iron, even when its crystalline state is as complete as possible; for even then the laminæ of cleavage occur in all directions, as is seen in a multiplicity of minerals and terrestrial rocks, such as lamellar limestone. Other procedures also have been employed for studying the structure of meteorites. (*Comptes Rendus de l'Académie des Sciences*, t. lxiv, p. 685, 1867; t. lxv, p. 148, 1867.)

The falls of iron meteorites are incomparably more rare, at least at the present epoch, than the falls of those of stone. There have been observed in Europe but two which were quite certain in more than a century: one in 1751, at Branau, in Bohemia; the other at Agram, in Croatia, in 1847. Nevertheless, there have been collected in different regions of the globe, particularly in Europe, in Siberia, the United States, Mexico, Brazil, and in Africa, metallic masses, to which their composition justifies us in assigning an extra-terrestrial origin with as much certainty as if they had been seen to fall. Three of these complete masses, which are in the gallery of the museum, afford an idea of the interesting peculiarities presented by the aspect and structure of meteoric iron. They display the fragmentary forms affected by these masses—forms which equally characterize, as will be seen further on, the stony masses, properly so called.

II.—METEORITES OF THE SECOND GROUP, OR SYSSIDEROUS.

Certain iron meteorites, in place of being massive, include *stony portions* disseminated in a *metallic paste* which possesses continuity and forms a sort of *metallic sponge*. They thus constitute a first term of the transition of meteorites of iron to those of stone.

In the best known representative of the meteorites of this second group, the stony matter, whose grains are imbedded in the iron, consists of a silicate with a base of magnesium and of protoxide of iron, constituting precisely the terrestrial species known by the name of *peridot*. This arrangement recalls in a striking manner certain products of iron accidentally formed in the workshops, in which the silicated scoria performs the part fulfilled by the peridot in the meteorites with which we are occupied. The meteorites of this second group are particularly represented by a celebrated mass of iron, discovered by Pallas, at Krasnojarsk, in Siberia, and by another altogether similar, which was found in the desert of Atacama, in Chili.

The stony matter of these meteorites, to which we give the name of *syssiderous*,* does not always consist exclusively of peridot. It sometimes comprises,

* From the Greek συν, (*with*,) to express the *continuity* of the iron, and σίδηρος, (*iron*.)

also, a silicate of a *pyroxenic* nature. This is the case in the meteorite of Toula, government of Perm, in Russia, the lithoid part of which affects a very remarkable breccia-form arrangement, as well as in that of Rittersgrün, in Saxony. In the two types of syssiderous meteorite which have just been cited, the stone is in grains disseminated and *discontinuous*. But it may happen that the stone therein is *continuous* as well and at the same time as the iron; that is to say, that the mass results from the mutual entanglement of the two continuous systems, the one metallic, the other stony. Such, among others, is the meteorite of Rittersgrün.

III.—METEORITES OF THE THIRD GROUP, OR SPORADOSIDEROUS.

The greater part of the meteorites are characterized by a *stony paste*, in which the iron, instead of being continuous, as is the two former groups, is disseminated in granules. The relation between the iron and the stone is then precisely the inverse of that which characterizes the type of Pallas and of Atacama. Each of these grains presents, moreover, the characters of composition and structure of the iron meteorites. Like them, they include nickel, and the phosphuret and sulphuret of iron. The grains of iron, otherwise very variable in proportion, have also very different dimensions, from that of a hazel-nut, or larger, down to grains scarcely visible, or even microscopic. Their form is very irregular and frequently tubercular.

In this series, the extreme terms of which are so remote, but which are connected by a multitude of intermediate bodies, we may distinguish three sub-groups.

FIRST SUB-GROUP, OR POLYSIDEROUS METEORITES.

In the first place, this sub-group, being the richest in iron, is represented by masses which their mixed composition might lead us to consider either as stone or as iron. We designate them by the name of polysiderous, (πολυς, *much*); the metal and the silicates may exist therein in apparently equal volumes. Among the meteorites pertaining to this sub-group we may particularize that which was found in Sierra de Chaco, Chili. The grains of iron in this meteorite, which are very voluminous and of a tubercular form, yield with acids the remarkable figures which we have described. In this experiment it will be observed that each grain is enveloped with a metallic pellicle more or less thin, the structure of which is much more confused than that of the mass. It would seem that at the periphery the crystallization had been embarrassed or troubled. The stony gangue, in which the metallic grains are imbedded, is essentially formed of silicates. If studied more closely, it will be found to result, in general, from the mixture, in variable proportions, of a basic silicate of magnesium, peridot, with a more acid silicate, known by the name of *pyroxene*.

SECOND SUB-GROUP, OR OLIGOSIDEROUS METEORITES, (COMMON TYPE.)

The meteorites incomparably most frequent enter into the sub-group at which we now arrive. In ten falls, nine at least pertain to it; hence it may be designated as the *common type*. We give to the meteorites which it comprises the name of *oligosiderous*, (ὀλιγος, *little*.)

These meteorites are easily distinguished by their stony aspect from those of the preceding sub-group, and of course more readily still from those of the two first groups. The fracture, ordinarily of an ashy gray and rough to the touch, recalls strikingly that of certain finely-grained trachytes. The mass is entirely crystalline, as the microscopic examination of a lamina sufficiently thin immediately evinces. The paste appears, at first view, almost homogeneous; but a more attentive examination enables us to recognize that it results from a mixture

of different substances which pertain, in general, to five species readily distinguishable: three metallic, two stony and silicated.

First, we find *nickeliferous native iron* in malleable grains, often very small, the composition and structure of which are identical with those of the iron meteorites already described; the proportion of these grains is widely variable, being ordinarily comprised between 8 and 22 per 100 of the total weight. Next, *sulphuret of iron* (troïlite,) of which the degree of sulphuration seems inferior to that of magnetic pyrites or pyrrhotine. It approximates to the proto-sulphuret; often occurs in isolated grains, which their color, a bronze yellow, renders easily discernible; often, also, it exists in the globules of iron, where it is imperceptible to the sight. It forms, in general, from 4 to 13 per 100 of the mass, and reaches even 20 per 100 in the meteorite which fell 24th December, 1858, at Murcia, in Spain. *Chromate iron*, which forms the third metallic element, appears in the meteorites under consideration in small black grains, analogous to those observed in the serpentines. This mineral represents only from 0.2 to 2 per 100 of the total mass. It was Laugier who, in 1806, pointed out the frequent occurrence of chromate iron in meteorites, (*Annales du Muscum*, t. vi,) a fact whose importance approaches that of the discovery of nickel, made by Howard four years earlier. Numerous analyses have subsequently confirmed the habitual presence of the chrome. But the prevailing constituent of meteorites of the common type is a mixture of silicates, which are separated in effect by the action of acids. One of these silicates, assailable even by weak acids, has most frequently the composition of peridot; the other, unassailable, is richer in silicic acid. Apart from the slight proportion of alumina, lime, and alkali which it includes, and which seems due to a mixture of other silicates, it often approximates to pyroxene.*

The meteorites of the common type very often present a globular texture—a substance, of a gray color a little deeper than the mass of the stone, formed of globules of different sizes. These globules are principally constituted by the bisilicate which we just now mentioned, and on which the acids exert no action. It thence results that if we dissolve the meteorites in question in an acid, there may remain at the bottom of the phial small grains not unlike gun-shot. M. Gustave Rose, struck with this remarkable structure, has proposed to give to the meteorites of the common type, in the majority of which this structure is clearly manifested, the name of *chondrites*, derived from the Greek word χονδρος, signifying *a ball or granular concretion.*

Another remarkable character, frequently afforded by meteorites of this subgroup, is to present surfaces of friction analogous to those mirror-like slides (*miroirs de glissement*) which are observed in some parts of the veins of mines. Their grains of metallic iron have been drawn out along those surfaces of friction, so as to suggest the influence of an energetic effort. These rubbed surfaces are abruptly interrupted by the external glaze, which shows that they have been produced previously, not only to the fall of the stones, but also to their division into fragments.

In the meteorites with which we are occupied, the external black frit or crust is always of a dull color. Most specimens of the stones of the common type present, after remaining some time in damp air, numerous spots of rust, owing to the easy alteration of several of the substances contained in them, and especially of the sulphuret of iron. This circumstance, perhaps, enables us to comprehend why it is that these meteorites are not met with on the surface of the earth, like

* Among the numerous analyses which have evinced this remarkable constitution, we will cite that which M. Damour has made of the stone which fell 9th December, 1858, near Montrejeau (Haute-Garonne). (*Comptes Rendus*, t. xlix, p. 31.) 'Nickeliferous iron, 11.60; magnetic pyrites, 3.74; chromic iron, 1.83; peridot, 44.83; hornblende albite, 38.00; total, 100. M. Dufrénoy had before made the analysis of the stone which fell 12th June, 1841, at Chateau-Renard (Loiret,) which pertains to the same type. (*Comptes Rendus*, t. xii, p. 1230.)

those of iron; the disappearance of a part of their elements may have brought on a total disintegration.

THIRD SUB-GROUP, OR CRYPTOSIDEROUS METEORITES.

In the meteorites of which we form the third sub-group, the iron is scanty, and its grains are so fine as to have passed unperceived until M. Gustave Rose demonstrated their presence. The name of cryptosiderous (κρυπτος, *hidden*,) expresses this character. This sub-group constitutes, in fact, a transition from meteorites containing metallic iron to meteorites destitute of it; it has thus been considered until the present time as pertaining to the latter.

But it is chiefly by the composition of the stony part that these meteorites differ from the preceding, that is to say, from the common or *oligosiderous* type. The principal section to be distinguished in the cryptosiderous series is that of the *aluminous* meteorites. It is characterized, in a mineralogical point of view, by a mixture of two distinct minerals, which often occur, however, in a state of confused crystallization, namely, *augite pyroxene* and *anorthite feldspar*. In addition, *magnetic pyrites* or *pyrrhotine* is also found, often forming hexagonal crystals perfectly distinct, as was long since observed by M. Gustave Rose.* The aluminous meteorites referred to this section have recently received from that eminent mineralogist the name of *eukrites*, from ευκριτος, *distinct*. The alumina and lime occur here in larger proportion than in meteorites of the common type, while on the contrary the magnesium is in less quantity.† It will be seen that this composition presents a certain analogy with some well-known lavas, such as those of Etna, formed of pyroxene associated with labradorite feldspar; while it approximates still more closely to the composition of other lavas with anorthite, which have been met with at the Thjorsà, in Iceland.

In the aluminous meteorites, the external coating is *lustrous* instead of being *dull*, as in meteorites of the common type; it is at the same time remarkable for the distinctness of the striæ and indurated globules which it presents. This twofold circumstance appears to correspond to a greater fusibility of the substance, due to the simultaneous presence of the alumina and lime. Besides the meteorite of Juvinas, may be cited, as pertaining to this type, those which fell 22d May, 1808, at Stannern, in Moravia, and 13th June, 1819, at Jonzac (Charente-inferieure). The presence in one of these meteorites, examined in 1825 by M. G. Rose, of minerals having the same crystalline forms with those of terrestrial mineral species, which have moreover the same composition, constitutes an important fact in the study of these cosmic bodies; for it serves to show the unity of the laws which govern the inorganic world throughout the immensity of space.

A second section comprises meteorites principally formed of magnesian silicates. It is represented by the meteorite which fell 3d October, 1815, at Chassigny (Haute-Marne). The magnesian silicate is peridot, which we have mentioned as existing in preceding groups, and which presents itself here, constitut-

* See, respecting the crystallized minerals which occur in meteoric stones, "*Annales de Chimie et de Physique*," 1826.

† As an example, we will cite the meteorite which fell 15th June, 1821, at Juvinas, (Ardèche,) the analysis of which, made heretofore by Vauguelin and by Laugier, has been lately repeated by M. Rammelsberg. According to the latter, the composition is as follows:

Pyroxene augite	62.65
Feldspar anorthite	34.56
Apatite	0.60
Titanite	0.25
Chrome iron	1.35
Magnetic oxidulated iron	1.17
Magnetic pyrites	0.25
Total	100.83

ing nearly the whole of the mass. It is identical with that which occurs on the earth, and contains disseminated grains of chrome iron.* On the stone of Chassigny, as on other meteorites, there is a crust resulting from a superficial fusion.

IV. METEORITES OF THE FOURTH GROUP OR ASIDEROUS.

The meteorites in which no iron disseminated in a metallic state can be recognized are rare, and the more attentively meteorites are studied with a view to the presence of metallic iron, the more is the number of the specimens of this last group reduced; it is nearly restricted at present to the *carbonaceous* meteorites. These present in their composition peculiarities of such a kind that it would have been impossible to believe in their origin, had not their fall been witnessed. A recent occasion has allowed these interesting bodies to be studied with minute attention. It is the presence of carbon which characterizes them, not free or in the state of graphite, as in certain ferruginous meteorites, but in admitted combination with hydrogen and oxygen; it is also the presence of combined water; finally, it is the presence of soluble, and even deliquescent saline constituents. To complete these distinctive characters, it must be added that a double carbonate of magnesium and iron, of the species *breunerite*, has been met with in the meteorite of Orgueil.

In certain respects carbonaceous meteorites ally themselves with those of which we have already spoken. Like the latter, they contain magnesian silicates, including sometimes oxides of nickel, cobalt, and chrome. There is found also oxide of magnetic iron, magnetic pyrites, innumerable microscopic crystals, having scarcely a diameter of 1.30 of a millimetre,† and finally chrome iron.

The presence of carbon, in a state of hydro-oxygenated combination, and analogous to the results of vegetable decomposition, has led to an investigation whether the carbonaceous meteorites might not contain remains which had belonged to living beings. But the most delicate researches have disclosed nothing of this kind. However this may be, the presence of substances easily volatilized, or alterable under the action of heat, would prove that at the moment when the carbonaceous meteorites penetrated into the atmosphere they were cold. The incandescence which they have undergone has produced, by the fusion of their superficial portion, a thin crust, but the weak conductibility of the constituent matter has preserved the internal parts from sensible alteration.

The carbonaceous meteorites, of which we possess specimens, are referable to four descents, all quite recent. The first took place at Alais, (Gard,) in 1803; the second at the Cape of Good Hope, in 1838; the third at Kaba, in Hungary, in 1857; and the fourth at Orgueil (Tarn-et-Garonne,) in 1864. We owe to Berzelius, Faraday, and M. Wœhler, the discovery of the principal facts relating to the constitution of the meteorites of this sub-group. More recently M. Cloëz

* The following is the result of the analysis which M. Damour has made of this interesting meteorite:

Silica	35.30
Magnesium	31.76
Protoxide of iron	26.70
Protoxide of manganese	0.45
Oxide of chrome	0.75
Potassium	0.66
Chrome iron and pyroxene	3.77
Total	99.39

This composition is that of the variety of peridot, rich in protoxide of iron, and known under the name of *hyalosiderite*. (*Comptes Rendus*, t. lviii, 1861.)

† Especially in the meteorites of Orgueil. *Comptes Rendus*, t. lviii, May 30, 1864.

has studied the carbonaceous meteorite of Orgueil, and chiefly the state of combination of the carbon, (*Comptes Rendus*, t. lviii, 1864). M. Pisani, on his part, has examined this last meteorite, principally with reference to the stony matter.

APPENDIX TO THE PRECEDING GROUPS.—PULVERULENT METEORITES.

The skies furnish not only coherent masses, stony or metallic, but also pulverulent matter. The existence of this meteoric dust has not attracted, so much as it should have done, the attention of savants. This circumstance may be referred to the extreme difficulty of distinguishing the dust which is truly cosmical, from that whose origin is terrestrial, and which is, beyond comparison, most abundant.

To the examples cited above, of the descent of terrestrial matter, we may add, as well-known, the pretended showers of sulphur resulting from the fall of pollenic dust, and certain silicious rains, which Ehrenberg has recognized as being formed by the carapace or shells of infusoria. But, apart from these terrestrial substances, we should distinguish those which are really cosmical. For example, in some meteoric falls, the stones have been accompanied by dust. Thus, 14th March, 1813, at the same time that there fell at Cutro, in the Calabrias, a quantity of stones, an abundance of red powder was collected.* Again, 5th November, 1814, it was remarked that the 19 stones picked up at Doab, in India, were enveloped, as it were, in a pulverulent matter.

In certain cases, the fall of dust has been observed without the accompaniment of stones, but always announced by those remarkable phenomena of light and sound which we have already described. The catalogue which Chladni published in 1842 makes known a number of examples, and among them the following. In 1819, at Montreal, (Canada,) a black rain was observed, accompanied by an extraordinary obscuration of the sky, by detonations comparable to those of discharges of artillery, and by the most brilliant gleams of light. At first the burning of some forest in the vicinity, in coincidence with a violent storm, was supposed, but the collective phenomena, and an examination of the matter which fell, analogous perhaps to the meteorite of Orgueil, proved that the disturbance was due to the arrival in the atmosphere of substances foreign to our globe. At Lœban, in Saxony, there fell, 13th January, 1835, a powder formed of oxide of magnetic iron. This followed the explosion of a bolide, which moved, it is said, with extraordinary velocity, while the detached fragments appeared to blaze in traversing the atmosphere.

It is perhaps to meteoric dust that we should ascribe the trails which follow the meteorites at the moment of their explosion; perhaps, also, it is to the combustion of this dust that the incandescence of bolides is in part due. The carbonaceous meteorite of Orgueil, so interesting in many points of view, has been highly instructive as regards the existence of meteoric dust. It is so friable that some pieces are reduced to powder by simple pressure between the fingers; it is matter of surprise that they should have reached the surface of the earth entire. This fact may perhaps be explained by remarking the two following circumstances: First, each fragment was enveloped, at the moment of its fall, in a vitrified crust, more solid than the rest of the mass. Besides, the different parts of the meteorite are cemented by alkaline salts; water, by dissolving this cement, occasions the complete disintegration of the meteorite, which is reduced to a dust of the utmost tenuity.† Had the sky, on the 14th May, 1864, instead

* *Bibliothèque Britannique*, 1813 and 1814. Admiral Krüsenstern was witness of a fact which should be cited on this occasion. He observed, in his voyage around the world, a bolide which left behind it a luminous trail, remarkable for its persistence; it continued to shine for an entire hour, without sensibly changing its place.

† The powder in question traverses even the closest filters.

of being perfectly clear, been rainy, or simply covered with clouds, through which those stones would have had to pass, such is their constitution that only a viscous mud would have remained to be gathered, similar to that which, on some occasions, has been observed to fall.*

The study of the meteorite of Orgueil shows, finally, that meteorite dust may be combustible, and contribute to incandescence by its oxidation. In view of these different facts, it cannot be questioned that great attention should be paid to the fall of atmospheric dust. It might be well, after the explosion of bolides, to seek in the air for this pulverulent matter, by all the means which science now places at our disposal, and to examine it, especially, with a view to detecting the presence of nickel.

Gaseous meteorites, (mentioned by way of suggestion). Does the celestial space ever furnish gaseous matter? This we know not; but without speaking of shooting stars, it is not impossible that certain meteorites, or the bodies from which they are detached, are provided with an atmosphere. Whether this be so or not, for the sake of completeness, and in order to call attention to the point, we include gaseous meteorites in our list.

§ 2. CLASSIFICATION OF METEORITES.

After indicating the different types to which meteorites may be referred, it is proper to express their relations by means of a classification. That which we here present, though otherwise very simple, has required the invention of a certain number of names, which, as indicated in the following table, will be found convenient. It comprises only groups and sub-groups; but each of the latter embraces several different types which need not be specified in so compendious a review:

Solid and Coherent Meteorites.

			GROUP.	SUB-GROUP.	EXAMPLES.	DENSITIES.
SIDERITES.—Meteorites containing iron in a metallic state	Not containing stony matter		I. HOLOSIDEROUS		Charcas	7.0 to 8.0
	Containing at the same time iron and stony matter	The iron presents itself as a continuous mass.	II. SYSSIDEROUS		Rittersgrün.	7.1 to 7.8
		The iron presents itself in disseminated grains.	III. SPORADOSIDEROUS	*Polysiderous.*—Quantity of iron considerable	Sierra de Chaco.	6.5 to 7.0
				Oligosiderous.—Quantity of iron small	Aumale	3.1 to 3.8
				Cryptosiderous—The iron imperceptible to sight	Chassigny	3.5
					Juvinas	3.0 to 3.8
ASIDERITES. Meteorites not containing iron in a metallic state			IV. ASIDEROUS		Orgueil	1.9 to 3.6

§ 3. COMPOSITION OF METEORITES COMPARED WITH TERRESTRIAL ROCKS.—SIMPLE BODIES.

From some hundreds of analyses, which have been conducted by the most

* Thus, in Lusace, 8th March, 1796, there was seen to fall, after the explosion of a bolide, a mass which was viscous, bluish, and probably carbonaceous.

eminent chemists, it results that meteorites have presented no simple body foreign to our globe. The elements which have thus far been recognized in them with certainty are 22 in number, and in the following enumeration are arranged very nearly in an order corresponding to the progressive diminution of their importance: *Iron* is absolutely constant, as well in a metallic state as in that of a sulphuret; in the stony masses it also occurs as an oxide, entering into different combinations of the protoxide. *Magnesium* is met with very generally in the state of a silicate; it has been recognized also in the constitution of the phosphurets mentioned above. *Silicium* gives rise to the silicates which constitute the principal mass of most meteorites. *Oxygen* is always present in the stony part of these bodies. *Nickel*, as has been seen, is the principal accompaniment of the iron. *Cobalt*, without being in as great proportion, is almost as constant. The same is the case with *chrome*, which is found in the stones in the state of chromated iron. *Manganese* has been often mentioned. *Titanium* is much more rare. *Tin* and *copper* have been discovered by Berzelius. *Alumina* exists in a certain number of meteorites, in the state of multiple silicates; so likewise do *potassium*, *sodium*, and *calcium*. *Arsenic* occurs in the peridot of the iron meteorite of Atacama. *Phosphorus* presents itself chiefly in the state of phosphurets, and sometimes of phosphates. *Nitrogen*, discovered by Berzelius in the carbonaceous meteorite of Alais, has been detected anew in the ferruginous meteorite of Lenarto by M. Boussingault. *Sulphur* very frequently forms sulphurets. Traces of *chlorine* are distinguishable in certain iron meteorites by the chloruret of iron which it produces after a time, and which falls into deliquescence. *Carbon* is found in iron meteorites, either as graphite or combined with the metal as a carburet. It exists also in the carbonaceous meteorites, in combination with oxygen and hydrogen, and in one such meteorite it has been met with in the state of a carbonate. *Hydrogen* also forms a part of the carbonaceous meteorites; quite recently M. Graham has given notice of its existence in the iron of Lenarto, in which nitrogen had been already detected.

COMBINATIONS COMMON TO METEORITES AND THE TERRESTRIAL GLOBE.

In the number of the combinations which these different simple bodies affect in meteorites, there are several which are found in the mineralogical species of the earth. Such are *peridot*, *pyroxene* and the *anorthite feldspar*, *chromated iron*, *magnetic pyrites*, and *oxydulated iron;* the last is singularly rare. *Graphite*, and probably *water*, may also be cited among minerals common to meteorites and the terrestrial globe.

Moreover, certain meteorites present mineralogical species associated after the same manner as in certain terrestrial rocks. It is thus that the stone of Juvinas approximates extremely to certain lavas of Iceland; that the stone of Chassigny offers all the characters of the peridot of the earth, with grains of chromated iron disseminated, exactly as in the peridotic rock called *dunite*, recently discovered in New Zealand; while the carbonaceous meteorites recall, in certain respects, some of our carbonaceous combustibles.

MINERALS PECULIAR TO METEORITES.

On the other hand, several mineralogical species are peculiar to meteorites, especially *nickeliferous native iron*, the *phosphuret of iron and of nickel*, (*schreibersite*,) and the *sulphuret of iron* (*troïlite*).

CHAPTER III.

SYNTHESIS OF METEORITES.—§ I. SYNTHETIC EXPERIMENTS RELATIVE TO METEORITES.

While the species common to meteorites and to the terrestrial globe disclose influences which have operated equally in these two orders of deposits, the species proper to meteorites indicate other and peculiar influences, an attentive examination of which leads to useful indications in regard to the mode of formation of these last bodies. Be it remarked, however, that we lay aside absolutely all consideration of the cause by which meteorites are brought into our atmosphere, in order to confine ourselves solely to the peculiarities of their structure and composition.

It has been sometimes thought that meteorites became crystallized in our atmosphere by the process of cooling undergone therein. Now, nothing of the kind exists. These planetary bodies reach us, it is true, in an incandescent state; but this incandescence never attains the interior of the pieces, even when they are of very small dimensions. Hence it follows that the interior condition of the mass is, to all appearance, identically what it was in cosmic space.

It has seemed to me that the moment was opportune for verifying by synthetic experiments the numerous ideas which analysis has furnished on the constitution of meteorites.* It might be hoped, in effect, that experimental synthesis would not render less service in this field of study than in that of minerals and terrestrial rocks.

FERRUGINOUS METEORITES.

We have seen above what is remarkable in the structure of these bodies, and what is due at once to the crystallization of the whole mass and to a segregation of like material. In seeking to reproduce that structure, I first melted the meteoric iron of Caille (Var) in a cement of alumina, avoiding the use of charcoal, which would have combined with it. The mass, after fusion, presented at its surface and in its fracture a distinct crystallization; but it no longer offered the brilliant lines which were so clearly delineated in the natural state. Perhaps the result had been more satisfactory if the cooling could have been effected in a very slow manner. It is proper to add, moreover, that the iron meteorites themselves do not always present the geometric regularity just indicated. There are those in which the phosphuret is isolated under rounded forms, quite irregular and often indistinct.

Another series of experiments had for its object to associate soft iron with each of the principal substances which accompany it in the meteorites, particularly with nickel, silicium, sulphur, and phosphorus. By associating soft iron with nickel, with protosulphuret of iron, and with silicium, masses were obtained of a dendritic or extremely crystalline structure, but offering no true segregation comparable to that of the ferruginous meteorites. It is otherwise if we melt soft iron with the addition of phosphuret of iron in a proportion which has been carried from 2 to 5 and 10 per 100. We then see isolated on the polished surface which has undergone the action of the acid a more brilliant and resistant substance which perfectly resembles that of the iron meteorites, excepting a less degree of regularity in the figure. A still better result has been obtained by introducing nickel at the same time with the phosphuret of iron, and especially by operating on considerable masses, the weight of which reaches from two to seven kilograms. In the midst of dendritic figures of a remarkable regularity, and which, accord-

* "Comptes rendus," t. lxii, pp. 200, 360, 669. "Bulletin de la société géologique de France," 2d series, t. xxiii, p. 291, 1866.

ing to an examination made by M. Des Cloizeaux, appear disposed in the forms of the regular rhomboidal dodecahedron, we then perceive the brilliant matter, isolated, and, as it were, driven into the interstices, under a reticulated form.

STONES.—FUSION.

As meteoric stones always reach us covered with a black and vitreous crust, due to a superficial fusion effected in their transit through the atmosphere, it might be thought that by melting them in crucibles we should obtain nothing else but this same vitreous matter; but experiment has taught that it is quite otherwise, and that these substances possess, on the contrary, a very decided aptitude for crystallization. Thus, by liquefying the meteorites of more than thirty different descents, I have always obtained masses eminently crystalline.

If *meteorites of the common type* be submitted to a temperature sufficiently high, the mass, after fusion, is composed of a precipitate of small metallic grains disseminated in a silicated gangue of lithoid appearance. This lithoid part itself is generally divided into crystalline substances, very distinct in form. The one consists of rectangular octahedrons, much flattened, and having the form and arrangement which characterize *peridot*, especially that which is formed in scoriæ. This same substance is presented under two other forms in the products of fusion.* The second substance habitually presents prisms with a rectangular section, often aligned parallel with one another, and having a fibrolamellar fracture which strongly resembles that of *bronzite*. Their opacity does not ordinarily permit of its being decided whether they pertain to the right system of the rhomboidal prism or to the oblique system. Yet as they are, for the most part, devoid of iron, and contain scarcely more than magnesium, they must be considered as pertaining not to pyroxene, but to the species *enstatite*. Moreover, on the product of the fusion of the meteorite which recently fell at Tadjera, in Algiers, numerous uncolored needles are to be observed which, examined with the microscope, show very distinct angles approaching to 87°, like those which correspond to the cleavages of enstatite, (*Comptes rendus*, t. lxvi, p. 517, 1868). The chemical assay of these two substances justifies the conclusion to which we are led by the crystallographic examination.

We have seen that the analysis of most meteorites of the common type discloses the existence therein of at least two silicates; the one alterable, the other unalterable by acids. In the experiments of which I have just given an account a parting takes place between these silicates which were originally in such intimate intermixture that they could not be distinguished. They separate by a sort of liquation, and much more distinctly than in the natural meteorite; it is thus that, under different forms, the magnesian silicates, peridot (Mg. Si.) and enstatite, (Mg. Si^2.,) make their appearance. The relative proportion of peridot and of enstatite, in the products of the fusion, vary much with the meteorites; it is generally the enstatite which predominates, and in a certain number, (Chantonnay, Ensisheim, Agen, Chateau-Renard, and Vorcillé,) the peridot does not appear in distinct crystals. On the contrary, the peridot may show itself in predominance, as in the meteorite of New-Concord. The reduction of the iron, which was in the state of a silicate, does not appear to have had any other effect than to augment the proportion of enstatite at the expense of that of peridot, without other change in the nature of the compounds.

The situation of these two species respectively, within the mass obtained, deserves attention. In general, the peridot, when it exists, forms at the surface

* According to the examination which M. Des Cloizeaux has made, one of these forms is of crystals with six faces, composed of the base P of the prism g_2, and of the truncation g_1; the other form is composed of the base P and of two basils, (*biseaux*,) of which one placed on the obtuse angles of the primitive prism of 119° 30′, pertains, by the angles, to the form a_1, while the other is placed on the acute angles.

a thin and crystallized pellicle, while the interior is composed of long crystals of enstatite which traverse it: these two substances are thus grouped conformably to their order of fusibility. Very frequently the needles of enstatite extend to the surface of the mass, with an arrangement which perfectly resembles that of the mica called palmate, contained in certain pegmatites of the Pyrenees and the Limonsin. This dendritic grouping of the enstatite has a very decided tendency to arrange itself under a constant angle. There is observable, also, in the two species of magnesian silicate, a remarkable tendency to group themselves regularly one on the other, as is seen in the staurotide and the disthene; and certain crystals having the form of peridot serve, as it were, but for the union of the numerous needles of enstatite which traverse them, thus recalling the structure of certain pseudomorphs.

These mixtures, easily discernible by the naked eye, pass into others which are indiscernible, and in which the substance, having a homogeneous appearance, like certain natural meteorites, betrays its compound nature only by a separation in the presence of acids. It should be remarked, further, that meteorites include certain substances, such as the silicate of alumina, which form no essential part of the peridot nor of the enstatite, but which remain hid in the crystals of these two mineral species, doubtless by virtue of the affinity which M. Chevereul has termed *capillary*. * * * The *aluminous meteorites*, of which those of Juvinas, of Jonzac, and of Stannern afford the best-known examples, give a product entirely different from all the magnesian meteorites which we have been considering: it is a vitreous mass, sometimes ribanded by incipient devitrification, but without crystals of peridot or of enstatite.

In the course of these investigations the presence of a body has been recognized which does not appear to have been observed until now in the magnesian meteorites; I speak of titanium, distinguishable by its characteristic color and its unalterability on contact with acids, and which has been thus detected in the melted meteorites of Montrejeau and Aumale.*

IMITATION OF METEORITES OF THE COMMON TYPE BY REDUCTION OF SILICATES.

The fusion of meteorites of the common type produces, as has been seen, two principal minerals, peridot and enstatite. Hence it was to the terrestrial rocks characterized by the presence of these two minerals that resort was had, in the first instance, for the experiments in contemplation. The first step was to fuse them in crucibles of earth without the intervention of a reducing agent.

By simple fusion in such a crucible peridot was converted into a green translucent mass covered with crystals of peridot and entirely crystalline in the interior, as appears by its action on polarized light. Its structure is often lamellar, like that of the peridot of the scoriæ.† The fused peridot contrasts, therefore, by its consistence with the granular and but little coherent peridot usually contained in basaltic rocks.‡ Lherzolite, formed of a mixture of peridot, enstatite, and pyroxene, melts still more readily than peridot, and gives masses which reproduce the natural rock so as to be easily mistaken for it; with this difference, that, on the surface and in the interior, needles of enstatite may be observed, which were not distinguishable before the fusion. Thus the needles, perfectly

* This metal, announced in the pyroxenic meteorite of Juvinas, by M. Rammelsberg, has appeared, also, very clearly on the globules of iron obtained by the fusion of that meteorite.

† The peridot on which most of the experiments here cited were made comes from the basalt near Langeac, (Haute-Loire,) where it abounds. A peridot of this locality, analyzed by Berthier, yielded 16 per 100 of protoxide of iron.

‡ The basalt appears not to have had, at least in general, a temperature sufficiently high to melt the large fragments of peridot which were imbedded in it. Yet it may, perhaps, have been capable of dissolving a part, and have thus given rise to the crystals, well defined but of small dimension, which are sometimes disseminated through it.

white, furnished by the lherzolite of Prades (in the Pyrenees) yield on analysis in 100 parts: *

		Oxygen.	Ratio.
Silex	57.0	28	2
Magnesium	42.0	15	1
Protoxide of iron	3.0		
	98.4		

Certain basaltic peridots, mingled with pyroxene and enstatite, offer the strongest resemblance to lherzolite, and, under the action of fire, deport themselves in the same manner. For instance, the needles obtained by the fusion of the peridot of Beyssac (Haute-Loire) give in 100 parts:

		Oxygen.	Ratio.
Silex	56.4	28	2
Magnesium	39.0	15	1
Protoxide of iron	3.0		
	98.4		

By the addition of a certain quantity of silex, the proportion of bisilicate or enstatite may be augmented at will, and produce those mixtures which form the transition from peridot to lherzolite. The same bisilicate is generated along the walls of the crucible by borrowing silex from them. I will remark here that by adding to peridot 15 per 100 of silex, the quantity necessary for its conversion into enstatite, and then melting it in the midst of charcoal, we obtain a mass covered on its surface with flattened rectangular octahedrons of the form which belongs to peridot, while the interior consists of a fibrous mass unalterable by acids, which has the characters of enstatite. An identical fact takes place in the fusion of certain meteorites.

The minerals, which had been first submitted, as above, to simple fusion, were next subjected to the same action in the presence of a reductive influence. For this purpose charcoal disposed as brasque in a crucible was first adopted. The same results as before were thus reached, with this difference only, that the iron, which was combined in the silicate, is reduced to the metallic state. It separates into precipitate and granules or remains disseminated in the undecomposed silicate in microscopic grains separable by the magnetized bar; at the same time, the portion of silicic acid corresponding to this iron contributes to augment the proportion of the bisilicate. All the iron, however, is not reduced to the metallic state; a part remains in combination in the silicate; and it is worthy of remark, that the green coloration, so characteristic of peridot or olivine, gives place to a general gray tint analogous to that of meteorites of the common type.

This product of the reduction and fusion of peridotic rocks greatly resembles, therefore, that of meteorites treated in the same manner. The analogy subsists, in a striking manner, for the stony part; it equally subsists for the metallic part. In effect, the metallic iron, proceeding from the reduction of the peridot of Langeac, contains 0.6 per 100, or 0.006 of nickel. That furnished by the lherzolite of Lherz likewise contains nickel and phosphuret in addition. I have obtained

* These different chemical analyses were made by M. Stanislas Meunier, assistant naturalist at the museum of natural history.

results still more decided and characteristic by operating on masses of peridot and lherzolite weighing as much as 12 kilograms. Precipitates of iron, relatively voluminous and susceptible of being submitted to the experiment of Widmanstätten, have thus been obtained; also a very distinct parting and the appearance of a regular figure produced by the unattacked matter.

Further, it has thus been possible to observe a fact which in operating with small granules had passed unperceived, but the importance of which will not escape those who have had occasion to examine the natural external surface of masses of meteoric iron. I speak of the angular forms, such as are presented by the iron meteorites of Charcas and of San Francisco del Mesquital, and also of those problematic capsules, such as are displayed particularly by the first of these blocks, and still more distinctly by that of Juncal, (*Comptes Rendus*, t. lxvi, p. 701, 1868.) Certain of these granulations present the angular forms, and their artificial surfaces bear, moreover, depressions here and there, characters wholly analogous to those which we have just recalled. They have manifestly originated during the cooling by a sort of moulding of the iron against the stony matter, which has become tough, if not solid, when the iron was still possessed of fluidity. In presence of this result, we would seem to be brought back to the hypothesis enunciated on occasion of the iron meteorite of Toula, and the angular forms of the meteorites of Charcas and San Francisco del Mesquital, (*Comptes Rendus*, t. lxvi, p. 573,) according to which hypothesis the meteoric irons were produced in the midst of silicated masses, between which they were moulded and from which they were ultimately detached.

We have thus seen meteorites reproduced in the general features of their composition; we will find that they have been imitated with equal success in certain intimate details of their structure.

If we examine with the microscope a thin lamina of peridot or lherzolite after fusion, we observe, as in the greater part of meteorites of the common type, those series of parallel straight lines resembling strokes of the burin, remarkable for their regularity, in the midst of clefts of irregular form. These lines are owing to the existence of planes of cleavage. Moreover, fine needles of enstatite, parallel and perceptibly equidistant, arranged also in clusters, recall the details of texture disclosed by the microscopic examination of a number of meteorites.*

The globular structure is so frequent in meteorites of the common type that it has earned for this whole group the denomination of *chondrite*. Now, we see similar grains, or spherules, make their appearance in many of the experiments conducted by the fusion of magnesian silicates. Among these globules some have a smooth surface, others a drused surface, or one rough with small microscopic crystals. The latter entirely resemble the globules of the meteorite of Sigena, (17th November, 1773,) of the friable variety. These globules are not attacked by acids, like those of the meteorites. The analysis of a specimen has shown that it contains more silex than the bisilicate. Lastly, the surfaces of friction, with a coating of graphitic appearance, which many meteorites present in the interior, as, for example, that of Alexandria, (2d February, 1860,) are well imitated with the fused silicates which contain iron reduced to very small grains, when two fragments are rubbed one against the other.

In another series of experiments, hydrogen, not charcoal, was employed as the reducer, and the results were found to be of the same order; thus, lherzolite and pyroxene exposed to a current of hydrogen abandon, in the state of metal, the iron which existed in the form of silicate of protoxide. The reaction may be effected at a temperature which does not exceed the red. Under these same conditions the phosphates, whether alone or in the presence of the silicates, are

* Apart from the instance of the meteorite of Aumale, I will refer the reader to those which are figured in the important work of my learned friend Gustave Rose, for the meteorites of Krasnoi-Ugol, of Stauropol, and for the peridot of the iron meteorite of Pallas, (Pl. i, Fig. 10, and Pl. iv, Figs. 7, 8, 9.)

reduced to phosphurets, so that the final product of the action of the hydrogen presents a great chemical analogy with the meteorites.

IMITATION OF METEORITES OF THE COMMON TYPE BY OXIDATION OF SILICIURETS.

There is a second method by which we are enabled to effect the imitation of meteorites. It is the inverse of the preceding, and consists in heating the dominant bodies of meteorites of the common type, other than the oxygen, that is to say, the iron, the silicium, and the magnesium, in an atmosphere incompletely oxidizing, and by conducting the process not only to roasting, but fusion, or in effect to scorification.

By exposing to the high temperature of the gas blow-pipe siliciuret of iron contained in a brasque of magnesium we obtain a perfect imitation, in all that is essential, of meteorites of the common type. The iron is separated, as well in a metallic state as in that of a silicate, and peridot is produced, partly in a crystallized form. This peridot presents divers shades, among others the olive tint which is habitual to it in nature. * * * * * * *

§ 2. DEDUCTIONS AS RESPECTS THE ORIGIN OF THE PLANETARY BODIES FROM WHICH METEORITES ARE DERIVED.—TEMPERATURE.

In the first place, is it possible to form an idea of the temperature at which the cosmical bodies in question are formed?

The experiments above stated seem to authorize us to assign to it certain limits. The temperature was doubtless high, since the anhydrous silicates, such as peridot and pyroxene, were produced. It appears, however, to have been lower than that at which the preceding experiments were conducted. Two facts lead us to this supposition. The high temperature employed in the laboratory resulted in the formation of silicates in well defined and voluminous crystals; such as are never met with in meteorites. It is worthy of remark, in fact, that the silicated substances, which compose the meteorites of the common type, are always in the state of very small and confused crystals, notwithstanding the strong tendency which they have to crystallize. Were we to seek some analogy in nature, we should say that the crystals obtained by the fusion of meteorites recall the long needles of ice which liquid water forms in congealing, while the fine-grained structure of natural meteorites resembles rather that of hoar-frost or snow, formed, as we know, by the immediate transition of atmospheric vapor to a solid state, or perhaps that of the flour of sulphur produced under analogous conditions. Moreover, in meteorites the form of the grains of iron is wholly irregular and, as it were, tubercular, (Sierra de Chaco). But the temperature employed in these experiments caused the metallic granules to take, in general, a spherical form; which is never observed in meteorites.

I have sought to imitate the mode of dissemination of metallic iron in silicates, as it occurs in common meteorites, by exposing to a high temperature an intimate mixture of reduced iron and lherzolite. After fusion of the whole, the particles of iron reunite in numerous and still very small grains, the globular form of which, easily distinguishable, especially after the specimen has been polished, contrasts with the grains of tubercular form disseminated in the meteorites.

Let it be distinctly observed that, in all cases, this original heat does not exist when the masses penetrate into our atmosphere. In effect, the carbonaceous meteorite of Orgueil is composed of a stony matter, holding in combination, or in intimate mixture, even in its central parts, water and volatile substances; it is, by reason of so sensitive a nature, a true thermometer *à maximum*, which indicates to us that these bodies could not be else than cold at the moment

of their arrival in our atmosphere, for it is not in the latter that these volatile compounds can have been incorporated with them.

CHEMICAL CONSTITUTION AND MODE OF FORMATION.

After the experiments which we have detailed, the very characteristic nature of the masses from which meteorites proceed may be readily explained, and that in a two-fold manner, according as we have recourse to the experiments of reduction or to those of oxidation.

It has been seen that the characters of meteorites are reproduced, even to the intimate details of their structure, in the reduction of basic silicated rocks by means of charcoal. Let us not conclude, however, that the meteorites have been formed by this process; for if this were so, the carbon would doubtless have carburetted the iron in a very considerable degree, as in steel or in casting, which is not ordinarily the case. Moreover, there is room for asking, in the case in which the formation of meteorites may have been accompanied by a reductive action, whether it would not be necessary to attribute it rather to a hydrogenated atmosphere.* The ingenious experiment by which M. Graham has verified the presence of hydrogen in a state of occlusion in the meteoric iron of the specimen of Lenarto, would serve as a confirmation of this idea, which had been announced previously to the discovery of the eminent English chemist, (*Comptes Rendus*, 19th February, 1866, t. lxii).

In place of considering the cosmical bodies with which we are occupied as the result of a reduction of silicated rocks, perhaps it is more simple and conclusive to have recourse to the idea of an oxidation analogous to those which we have artificially realized. Let us suppose, as has been done for our globe, that the silicium and metals of the meteorites have not always been combined with oxygen, as they are at present for the most part, and this, perhaps, because the initial temperature of these bodies was sufficiently high to prevent them from entering into combination, or because, being at first at a distance, they did not approach one another.

If, in consequence of refrigeration, or from any other cause, such as an approximation of these bodies, the oxygen comes to act suddenly, it will unite itself with the more oxidable elements. The silicium and magnesium will burn before the iron and nickel; and if the burning gas is not sufficiently abundant to oxidize the whole, or if it does not act during a sufficient time, it will leave a metallic residue composed of the less oxidable bodies; these metals, the iron and nickel, must remain disseminated in a gangue of silicates while retaining their metallic state, exactly as we observe it in the meteorites. Moreover, there will be thus formed a silicate of magnesium more or less rich in protoxide of iron, having the composition of peridot.

As is now seen, if we suppose the oxidation pushed successively to different degrees, the preceding experiments explain not only the formation of meteorites of the common type, but also that of the group of syssiderous and of the subgroup of polysiderous meteorites. These bodies are, therefore, to be assimilated to products by the dry way. This mode of formation appears not to apply so well to the meteorites pertaining to the group of *cryptosiderous*, and particularly to those of the type of Juvinas, of Stannern and of Jonzac. It has been seen how close an analogy allies them with certain aluminous lavas formed of pyrox-

* If these meteorites have been thus formed, there must have been water produced on the surface of the bodies of which they made a part. But those bodies may not have been able to preserve the water by reason of their small dimensions. Further, the reduction, if it has taken place, could only have been partial; for, in general, the iron is but reduced in part, whether in a metallic state or in the state of a sulphuret or phosphuret; another part of this same metal is ordinarily combined, as protoxide, in a silicate, and also in the state of chromated iron, (chromite of protoxide of iron.)

ene and anorthite. Now water, in the presence of which these last were formed, could have been no stranger to their crystallization. In no case do these rocks crystallize under the conditions of dry fusion, as the magnesian silicates so readily do; fusion transforms them into vitreous and amorphous masses. Hence, the meteorites of this last type seem rather products by the mixed way, which we might imitate, perhaps, by operating in water overcharged with heat.

As to the carbonaceous meteorites, they differ from all others, in that, doubtless, several of the substances which constitute them have been formed at a temperature but little elevated. At first view, we might be tempted to consider them as planetary vegetable earth; but it is possible, and the supposition is even probable, that these carburetted compounds have been formed without the concurrence of life and represent the last terms of certain reactions.

§ 3. DEDUCTIONS AS RESPECTS THE FORMATION OF THE TERRESTRIAL GLOBE.—ANALOGIES AND DIFFERENCES BETWEEN METEORITES AND TERRESTRIAL ROCKS.

We have seen above how much analogy of composition exists between meteorites and sundry terrestrial rocks. Not only do they include the same simple bodies, but the three bodies which predominate in the series of meteorites, namely, the iron, silicium, and oxygen, are also those which predominate in our globe; besides, we discover therein mineral species common to both and associated in the same manner.

It should here be remarked that the rocks which offer such traits of resemblance with the meteorites all pertain to the deep regions of the globe. They are eruptive masses of a basic nature, or lavas, or peridotic rocks, the reservoir of which is situated below the granitic stratum. We will recall (1) the lava formed of anorthite and of pyroxene, and such as has been found at the Thjorsa, in Iceland, for its approximation to the aluminous type (or that of Juvinas), the sixth of the seven principal types of meteorites which have been established above; (2) the peridot and the lherzolite, which present striking resemblances with the silicated part of the magnesian meteorites, and particularly with those of the common type. We know, from the examination made of it by M. Damour,* that the lherzolite is composed of peridot, with which are united enstatite, pyroxene, and sometimes spinelle, (picotite). The magnesian meteorites may also be compared to the hypersthene, pervaded by grains of peridot, which has been brought from Labrador.

But by the side of these resemblances between meteorites and certain terrestrial masses there exist differences which deserve no less to fix our attention. These differences bear essentially on the state of oxidation of the iron. Meteorites, like terrestrial rocks, contain protoxide of iron combined with silicium (silicate) and with the oxide of chrome, (chromated iron). On the contrary, oxydulated iron, so frequent in our basic silicated rocks, fails, in general, in the meteorites. It is there replaced, in some sort, by native iron, which, on the other hand, is wanting in our rocks.†

There is a second difference of the same character with the preceding. The

* *Bulletin de la Société géologique de France*, 2d sérue, t. xix, p. 413. On this occasion, it is mere justice to acknowledge the acuteness of observation of M. Lelièvre, who as early as 1787, in announcing the discovery of this remarkable rock, already recognized it as a variety of chrysolite, or peridot, (*Journal de Physique*, May, 1787, letter to de la Metherie.) Twenty-five years later, M. de Charpentier supposed he had demonstrated this same rock to be no other than a pyroxene in mass, and this conclusion was hastily and very generally adopted. The variations presented by lherzolite serve to explain the too absolute conclusion of a mineralogist so experienced.

† It is true that oxydulated iron is found in the carbonaceous meteorites, such as that of Orgueil; but these last pertain to a rare and wholly special category.

phosphuret of iron and of nickel, first recognized by Berzelius, is found almost always associated with the meteoric iron. This, like native iron, is entirely deficient in our rocks, where it is replaced by the phosphates particularly frequent in the basic silicated rocks.*

Without insisting further on some other contrasts of the same nature, we recognize that the essential difference between these meteorites and the analogous terrestrial rocks consists in this: that the first contain, in a reduced state, certain substances which the second contain in an oxydized state. Everything leads to the belief that masses between which there exists such a similarity of composition would have been identical, notwithstanding their immense separation, if they had not undergone different actions.

IMPORTANCE OF THE MAGNESIAN ROCKS OF THE PERIDOT TYPE, AS WELL IN THE TERRESTRIAL GLOBE AS IN OUR PLANETARY SYSTEM.

Among the basic silicates there is one which presents itself with remarkable constancy in almost all the varieties of meteorites, from those of iron to those of stone, properly so called; this is peridot. In the latter it is rarely solitary (Chassigny); commonly it is mixed with more acid silicates, often in undiscernible parts.† On the other hand, peridot necessarily exists in the profound depths of our globe.

In effect, the basalts of the most distant regions have brought up fragments of it, which often remain angular, and which would be pronounced to have been torn from a deep and pre-existent mass. Detached peridotic masses abound, as is well known, in different volcanic regions of France, (Langeac, Haute-Loire, Monferrier, Herault,) on the banks of the Rhine (environs of Lake Laach,) and in other countries. At the same time there are other pyroxenic rocks in which peridot is abundant, as, for example, in the dolerites of the environs of Montarville and of Montreal, in Canada, wherein, according to M. Sterry Hunt, (*Geology of Canada*, pp. 464, 706,) it forms sometimes nearly half of the total weight. Rocks rich in peridot have also been met with, traversing the chalk, in the neighborhood of Teschen, in Bohemia, and have been described by M. Tschermak, who has recently published a notice on the presence of olivine in rocks, (*Bulletin de l'Académie de Vienne*, 11th July, 1867). Again, peridot constitutes the base of the lherzolite which has made an eruption at many points of the Pyrenees, among others, near the lake of Lherz, and which occurs in other countries. Thus it is known in the Tyrol, and but a few years ago was discovered in New Zealand, where it forms an entire chain, by M. de Hochstetter, who has given it the name of *dunite;* more recently still it has been found in Nassau, at Trigenstein, by M. F. Sandberger, who calls it by the name of *olivinfels*, (*Leonhard's Jahrbuch*, 1865 and 1867.) To this it may be added that M. Kjerulf has lately ascertained that a rock which abounds in the environs of Bergen, Norway, and which M. Keilhau had heretofore considered as a metamorphic grit, is composed in part of nickeliferous peridot, with which are associated chromated iron, and talc. It may be further noticed that, after having recognized peridot in the rock of Elfdalen, in Sweden, M. G. Rose has found it also in the augite rocks of Neurode, in Silesia.

We are thus led to recognize that the part fulfilled by peridot, so restricted

* The stone of Juvinas, in which M. Rammelsberg has announced iron in the state of a phosphate, only affords confirmation of this rule; for it contains metallic iron only in the minutest quantity. It was difficult, therefore, that any phosphuret of that metal should be formed.

† Of more than 150 meteoric falls represented in the collections, we possess as yet only four which pertain to the aluminous type, being those of Juvinas, Jonzac, Stannern, and Petersburg, (United States.) The others are magnesian meteorites, which, almost all, contain peridot.

on the surface of the earth, is, beyond doubt, predominant at a certain depth. Hence, its importance may be inferred as well in regard to our globe as to the rest of our planetary system, as far, at least, as we can judge of the latter by the specimens which reach us. The rocks of peridot, therefore, excluded until now from the general classifications of lithology, would seem destined to hold hereafter a special and considerable place in them. By annexing serpentine to the rocks in question we might comprise them under the name of the *peridotic family*, or that of *cosmical rocks*.

There is, in the mean time, no room for surprise that peridot does not come in greater abundance to the surface of the globe. It is, in effect, the most basic silicate that is known, and it has a strong tendency to take up silicium and to become transformed into a more acid silicate, such as enstatite or pyroxene, as is shown by the experiments heretofore detailed. Now, to come from its primitive seat to the surface, it must necessarily have traversed rocks more acid than itself, and having kilometers of thickness. On these it would inevitably react, and may thus have given rise to those pyroxenic or amphibolic rocks which are so numerous, and which establish a sort of transition between pure peridot and pyroxene. Perhaps it is to reactions of this kind that we must attribute those gradual passages of lherzolite to pyroxenic or amphibolic rocks, of which the Pyrenees present examples at many points.*

TRANSFORMATION OF SERPENTINE INTO LHERZOLITE OR INTO PERIDOT.—THEORETICAL DEDUCTIONS.

There is another magnesian rock which it is proper to place near the peridot and the lherzolite, notwithstanding the differences which separate it from these last. Serpentine presents itself among eruptive rocks, with exceptional characters, as being at once hydrated, infusible, and without distinct crystallization. Geologists admit, generally, that serpentine results from the transformation of another rock, and that it is derived from peridot, at least in certain cases where it has preserved the characteristic form of the crystals of that substance.

Deferring the realization of serpentine from peridot as being at the present moment impracticable, I have been content to follow the inverse order, that is, to transform serpentine into peridot. Here the relative composition of the two minerals pointed out the course to be pursued; the serpentine differs from peridot only in containing water and including more silicium or less magnesium. It was requisite, therefore, to fuse the serpentine with the addition of magnesium in order to realize the constitution of peridot.

By treating in this manner the serpentines of Snarum, in Norway; of Monte-Ferrato, in Tuscany; of Sainte-Sabine, in the Vosges; and of Gaito, in Isera, I obtained, after fusion, masses confusedly crystalline and offering in many of their parts all the characters of peridot. Needles of enstatite are frequently disseminated therein or cover the surface. The presence of this bisilicate is explained by the fact that the specimens operated upon might include a little more silicium than the type of the formula ($Mg^3\ Si^4$) with which I had started.

These results have led me to examine the product of the pure and simple fusion of serpentines. The experiment made, in crucibles of earth, on specimens of different origin (Snarum, in Norway; Zœblitz, in Saxony; Favero, in Piedmont) has also yielded mixtures of peridot and of enstatite, though, in these, the former mineral appears in smaller proportion than in the fusions made in presence of magnesium. The serpentine of Baldissero, in Piedmont, known by the veins of magnesium and resinite quartz which it has secreted, has presented the result best characterized; needles of enstatite grouped with remarkable regularity, parallel with one another and in clusters, detach themselves in the midst of the

* De Charpentier, *Essai sur la constitution géognostique des Pyrenées.*

crystalline peridot;* it is identically the same product yielded by lherzolite. It should be remarked, however, that when serpentine is melted, without any addition, in a crucible, it cannot fail to take up from the walls of the latter some of its elements, and particularly silex.

In these fusions, as in those of meteorites, the tendency which the peridot and enstatite have to crystallize causes them to appear in very distinct crystals; but the product obtained includes, moreover, other silicates, aluminous or otherwise, which remain intimately intermixed, and, as it were, dissolved in the interior of the former.

These various results, the last especially, show that serpentine has often a decided tendency to change into peridot, as if it then only entered into its normal state. This is a reason the more for considering serpentine, at least in a certain number of its repositories, as a peridot or a lherzolite which has lost a certain quantity of its magnesium, and has become hydrated, by an operation which recalls that of the conversion of feldspar into kaolin.

The direct observation of rocks confirms this conclusion. On the one hand, there exist lherzolites which gradually degenerate into serpentine, as is observed in certain localities of the Pyrenees;† at Brezouars, in the Vosges;‡ at Neurode, in Silesia; and in the rock known by the name of *schillerfels* or *bastite* in Transylvania,§ in Nassau, and elsewhere.|| On the other hand, there are serpentines which manifest as clearly their relation with the peridotic rocks. A more demonstrative instance of this fact cannot be seen than in the serpentine of Baldissero, of which I have already spoken. One of the varieties of this serpentine pertaining to the collection of the Museum, where it was placed by M. Cordier, perfectly recalls, in its external characters, the lherzolite of the Pyrenees. I have recognized, moreover, that, like the latter, it is interspersed with crystals of enstatite of the bronzite variety, with pyroxene diopside of an emerald green and chromiferous, as well as with black chromiferous spinelle, sometimes in regular octahedrons, (variety called *picotite.*) These three mineral species present in both rocks exactly the same facies. Yet, notwithstanding these analogies, the serpentine of Baldissero is distinguished from lherzolite by its imperfect hardness and its persistency in water; it constitutes, as it were, one of the states of transition of the first rock to the second. The minerals which have resisted hydratation remain as witnesses of the primitive state, in such sort that the relation of kaolin to feldspar is not better demonstrated than the transformation which we are considering.

There is nothing to prove that the hydratation which has been produced in the transformation of peridotic rock into serpentine was effected by agencies on the surface of the globe. The eruptive serpentine of the Apennines, the Alps, and of so many different countries, may have been ejected from below after having already acquired the water which it contains to-day. The manner in which glass is decomposed in water super-saturated with heat and is changed into a hydrated silicate, as I have verified in former experiments,¶ would not seem to be without analogy with the reaction which may have produced the serpentine at the expense of pre-existent anhydrous silicates.

Not that I would pretend, however, that all serpentine masses result from the

* The pseudophite of Mount Zdiar, in Moravia, which contains enstatite and which differs from serpentine by the presence of alumina, does not yield very distinct crystals.

† De Charpentier, *Essais sur la constitution géognostique des Pyrénées.*

‡ Fournet, *Bulletin Soc. Géologique de France*, 2d series, t. iv, p. 227.

§ Tschermak, *Bulletin Acad. des Sciences de Vienne*, loc. citato.

|| In the new repository of lherzolite discovered by M. F. Sandberger, in Nassau, that distinguished geologist has observed all sorts of transitions of this peridotic rock into serpentine. *Leonhard's Jahrbuch*, 1865, p. 449.

¶ Synthetic experiments on metamorphism, (*Annales des Mines*, 5th series, t. xvi, p. 425.) On the formation of zeolites, (*Bulletin Soc. Geologique de France*, 2d series, t. xvi, p. 585.)

transformation of peridotic rocks; there are those, in effect, which have been considered as being derived from pyroxenic and other rocks. It is proper to observe on this occasion that the experiment by which I have shown above with what facility peridot is transformed into silicates less basic well explains, in general, the numerous transitions of serpentine to other rocks, as, in the first place, to euphotide, which is so ordinarily associated with it, as well as to the diorites and pyroxenic rocks, the prasophyres, &c., which accompany it in Tuscany,* in different regions of the Alps and in many other countries.

The analogies which subsist between serpentine and peridotic rocks have led to an examination of the former in reference to the synthesis of meteorites. If we melt serpentine in a brasque of charcoal the grains of iron which are separated from it often include nickel in considerable proportion, as when we operate upon peridot. For example, the iron extracted from the serpentine of Sainte-Sabine, in the Vosges, contains 0.67 per 100 of nickel. That of a serpentine of Mount Genevre has yielded it also, but in quantities too minute for accurate apportionment.†

To these traits of similarity of composition between serpentines and meteorites is to be added the presence of chrome. On the one hand, chrome is found in most of the serpentines, not only in the state of a green combination,‡ but also in the state of chromated iron, as is observed in the most different countries.§ On the other hand, the important observation made by Laugier in 1806,‖ namely, that chrome is rarely absent in meteorites, has but acquired confirmation. There are, in effect, very few stone-meteorites which are not mixed, at least in a small proportion, with chromite or chromated iron. Thus, apart from its persistency in water, serpentine may be assimilated to meteorites of the common type, almost as rightfully as peridot and lherzolite. It is proper further to remark that the carbonaceous meteorites (Cape of Good-Hope, Kaba, and Orgueil) appear to contain a hydrated magnesium silicate, which M. Wöhler states to be analogous to serpentine.

I will add an observation on the formation of spinelle, which is sometimes disseminated in peridot, as is seen in some localities of the Haute-Loire, in the lherzolite of the Pyrenees, and in the serpentine lherzolite of Baldissero.

Peridot being the most basic magnesian silicate which the rocks afford, the presence of this spinelle seems susceptible of easy explanation. As the alumina was disseminated in a very basic silicate, with which it could not dispute the silicium, nothing remained for it but to unite with the bases, magnesium and protoxide of iron. I have confirmed this supposition by a synthetic experiment. If we fuse the natural peridot, at a very high temperature, with alumina, (10 per 100,) we shall see, after the fusion, in the crystalline peridotic mass, small black grains which are infusible, unaltered by acids, and which contain, at once, alumina, magnesium, and protoxide of iron; some of them exhibit the form of the regular octahedron. These crystals, all of which have the characters of pleonaste spinelle, furnish a perfectly satisfactory reason for the formation of this mineral in the peridotic and the lherzolithic rocks.

CHARACTERS WHICH DISTINGUISH PERIDOTIC ROCKS.

Among the characters of peridotic rocks there are three which clearly distin-

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* Paul Savi, *Delle Rocce ofiolitiche della Toscana*, 1838, p. 11.

† It is proper to recall on this occasion that the nickel first indicated by Stromeyer, in certain serpentines, at the same time as in peridot, has since then been found in the serpentines of regions far remote from one another—in Saxony, in Silesia, in Norway, in Texas, in Pennsylvania; this metal is not wanting in the serpentines of Canada, according to the analyses of M. Sterry Hunt, (*Geology of Canada*, p 471.)

‡ Indicated long since by Valentine Rose and Klaproth.

§ Department of the Var, Saxony, Baden, the Austrian Alps, Moravia, Scotland, Norway, Greece, the Ural, numerous depositories in the United States, Canada, &c.

‖ *Annales du Museum*, t. vii, p. 395, 1806.

guish them from all other silicated rocks, and which deserve to fix the attention. (1) Peridot represents the most basic silicated type that is known, whether in the meteorites or in eruptive rocks. In that series of which it constitutes the first term and which terminates at the granite, it forms the species at once the most simple in composition and the best defined. (2) Under the point of view of the mode of crystallization, peridot, as well as the bisilicate of magnesium, or estatite, which is its frequent companion, is distinguished from the aluminous silicates, particularly from those of the group of feldspar, by the facility with which they are formed and become crystallized by the dry way, after simple fusion. On the contrary, it has never been found practicable to crystallize artificially, under the same conditions, anything having a resemblance, even remotely, to feldspar and to granite. (3) Rocks of peridot are very remarkable also by their great density, which is superior, as the following table will show, to that of all other eruptive rocks, and even to that of the basalts:

Granite	2.64 to 2.76
Trachyte	2.62 to 2.88
Porphyrite	2.76
Diabase	2.66 to 2.88
Basalt	2.9 to 3.1
Enstatite	3.303
Lherzolite	3.25 to 3.33
Peridot	3.33 to 3.35

These different rocks must at their origin have been superposed on one another in an order conformable to their augmentation of density. The great density of the peridotic rocks justifies the normal position which they appear to hold within the crust of the earth, beneath the granite envelope, beneath even the aluminous basic rocks.

COMPARATIVE DENSITIES OF METEORITES AND OF THE PRINCIPAL TERRESTRIAL ROCKS.

Setting aside the carbonaceous meteorites, which should be considered as outside of the series, we might conceive the meteorites to be disposed in concentric spherical strata, forming an ideal globe, whose density would go on increasing from the surface towards the center. At the exterior would be the aluminous stones; then would come the peridotic stones, those of the common type, the polysiderous, the syssiderous, and finally the holosiderous.

We may remark that this theoretical section is not without some analogy with an ideal section of the terrestrial globe, distinction being made of the sedimentary deposits and of the granito-gneissic stratum. In this section the lavas would correspond to the aluminous meteorites; below these the peridot would be the analogue of the stone of Chassigny; the lherzolite and other rocks of the same kind would well represent the meteorites of the common type. Here, it is true, stop the analogies which can be directly observed, but here also stops the knowledge which we have of the more profound regions of our globe. There is nothing repugnant to reason in supposing that these more profound parts of the earth afford resemblances to the ideal globe which we have just constructed by the superposition of the different kinds of meteorites; there is nothing to prove, in a word, that one of the globes does not complete the other.

This comparison, which may seem, perhaps, somewhat precarious, will be better understood by means of the following table, the first column of which con-

tains, with the densities, the principal types of meteorites, while the second column exhibits the principal terrestrial rocks:

I.	Densities.	II.	Densities.
"		Stratified formations	2.6
"		Granite and gneiss	2.7
"		Pyroxenous lavas	2.9
Aluminous meteorites	3.0 to 3.	"	
"		Peridot	3.3
Peridotic meteorites	3.5	"	
"		Lherzolite	3.5
Meteorites of the common type.	3.5 to 3.8	"	
Polysiderous meteorites, (Sierra de Chaco)	6.5 to 7.0	"	
		"	
Syssiderous meteorites, (Pallas.)	7.1 to 7.8	"	
Holosiderous meteorites, (Charcas)	7.0 to 8.0	"	
		"	
		"	

PERIDOT CONSIDERED AS A UNIVERSAL SCORIA.

The idea to which we have thus been conducted, in order to explain the origin of the planetary bodies from which meteorites proceed, illustrates also the mode of formation of that thick silicated mass which constitutes the external part of the terrestrial globe.

As early as the commencement of the century, Davy, after having made known the results of his admirable discovery of the composition of the alkalies and earths, supposed that the metals engaged in these oxides might exist in a free state in the interior of the globe; and he saw in their oxidation, by the access of water and air, the cause of the heat and eruptions of volcanos.

Subsequently this hypothesis has been enlarged by extending it to the origin of the terrestrial crust itself, which comprises, precisely in the state of silicates, the oxides of the metals most avid of oxygen; namely, potassium, sodium, calcium, magnesium, aluminum, and by considering even the water of the seas as the result of the combustion of the hydrogen in this general oxidation or conflagration. Sir Henry de la Beche, whose genius embraced all the great questions of geology, was among the first to propound this idea,* for which the way had been prepared by the important observations of Haussmann, Mitscherlich, and Berthier on the scoriæ of manufactures,† and which M. Élie de Beaumont has, with much justice, designated by the expression of *natural cupellation.* ‡ Without long explanations, it will be seen how this theoretic view is confirmed and justified by the results which I have obtained in the synthesis of the meteorites.

After what has been stated, it is natural to admit that the rocks of peridot, whose importance has been recognized in the constitution of the deeper regions of our globe, have the same origin with the similar silicates which form a part of the meteorites. These peridotic rocks would thus be, in our planet, the most direct product of a scorification which has been effected at an extremely remote epoch.

* *Researches in Theoretical Geology*, 1834. The French translation of this work was published in 1838, by M. de Collegno.

† Among the numerous observations of Haussmann, which extend back as far as 1816, I would expressly mention his memoir entitled *De usu Experientiarum Metallurgicarum ad disquisitiones Geologicas adjuvandas*, (Gœttingen gelehrte Anzeigen, 1837.) It is proper also to mention that as early as 1823, Mitscherlich recognized the forms of peridot and pyroxene in the crystals of metallurgic scoriæ (*Abhandlungen der K. Academie der Wissenschaften zu Berlin*, 1823, p. 25.)

‡ *Bulletin Soc. Geologique*, 2d series, t. iv, p. 1326, 1847.

It is essential to have a correct understanding respecting this term *scorification.* We know that when a bath of impure castings is kept in fusion in contact with the air, the iron is oxidized as well as certain bodies which are associated with it, of which silicium is the most important. The oxidation gives rise to a ferruginous silicate, which occupies the upper part of the metallic bath. This is a true liquid scoria; in cooling it will at first become doughy, then solid; and in the latter state will present a compact lithoidal crystalline structure; one wholly different, in a word, from the spongy and tufaceous substances to which we give the name of volcanic scoriæ. The former and metallurgic sense is that in which we understand the *scorification of the globe.*

As to the feldspathic rocks, many geologists consider that they have not been produced simply by the dry way, as we have just shown has been probably the case with the deep peridotic beds, but that they have been formed by the intervention of particular agents, among others of water. However this may be, we may here find, especially in the trachytes, the other extreme term of the series of masses silicated in the general scorification. The opposition between these two types, the most distinct and the best characterized, bears not only on the mineralogical composition and the circumstances of crystallization, but also on the density of these masses and their situation at depths necessarily very different. Let it be remarked further that this primitive scorification, extending through a thickness so considerable, may, even at the existing epoch, present, according to the depth, masses in the three states of which we have been speaking—solid, viscid, or liquid.

If metallic iron, quite habitual in meteorites, is wanting in terrestrial rocks, this difference may simply result from the circumstance that in our globe, where the oxygen of the atmosphere is in excess, the oxidation may have been *complete* and have left no metallic residue. When, however, we say that the terrestrial masses contain no native iron it is evident that the question only regards those which eruptions render accessible to our investigations; masses which, in view of the great dimensions of our planet, form but a sort of coating. There is nothing to prove that below those aluminous masses which have furnished, in Iceland, for example, lavas so analogous to the type of the meteorites of Juvinas, that below our peridotic rocks to which the meteorite of Chassigny so closely approximates, there do not exist lherzolithic groups in which native iron begins to appear; groups, that is to say, similar to the meteorites of the common type; then, going still lower, types more and more rich in iron, of which the meteorites offer us a series of increasing density, from those in which the quantity of iron represents nearly half the weight of the rock to the massive iron itself.

Some facts might, perhaps, be brought to the support of these views. Thus, platina, which its great density had probably placed, at the beginning, in profound regions, has, according to M. Engelhardt, been found associated with native iron. At all events, this last metal is allied to iron in a proportion which exceeds 10 per 100, and which suffices to render it strongly magnetic. It may be added that if, in the Ural, platina has never been found in place, it is often incrusted with chromate iron, and that it has even been met with still engaged in fragments of serpentine.* By this association, therefore, this metal seems to convey to us a new proof of the existence of magnesian rocks of the peridotic family, at considerable depths.

ABSENCE IN THE METEORITES OF STRATIFIED ROCKS AND OF GRANITE.

Meteorites, so analogous to certain of our rocks, differ considerably from most of those which form the terrestrial crust.

* G. Rose, *Reise nach Ural*, t. ii, p. 390. Le Play, *Comptes Rendus de l'Académie des Sciences*, 1846.

The most important difference consists in the fact that, in the meteorites, nothing has been found which resembles the materials that constitute the stratified formations—neither arenaceous rocks, nor fossiliferous rocks; that is to say, nothing which testifies to the action of an ocean on these bodies any more than to the presence of life.

A great difference is manifested, even when we compare the meteorites with the terrestrial rocks not stratified. Never has there been met with in the meteorites either granite, or gneiss, or any rocks of the same family which form, with these, the general layer on which rest the stratified formations. We do not even observe there any of the constituent minerals of granitic rocks—neither orthose, nor mica, nor quartz—any more than tourmaline and other silicates which are associates of those rocks.

Thus, the silicated rocks which form the envelope of our globe are wholly wanting among the meteorites. It is, as has been seen above, in the deeper regions only that we must seek the analogues of these latter; in those basic silicated rocks which only reach us in consequence of eruptions by which they have been expelled from their primitive repository. In every point of view, the absence in meteorites of the whole series of rocks which constitute, to so great a depth, the crust of the earth is a circumstance well calculated to arrest attention, whatever may be the cause.

This absence may be explained in different ways; whether it be that the meteoric fragments which reach us do but proceed from the internal parts of planetary bodies constituted like our globe; or whether these planetary bodies themselves are deficient in silicated quartziferous or acid rocks as well as in stratified formations. In this latter case, which is the most probable, they must have passed through evolutions less complete than the planet we inhabit; and it is to the co-operation of the ocean that the earth has owed, in its origin, its granitic rocks, as it has owed to the same agency, at a later period, its stratified deposits.

GENERAL OBSERVATION.

In fine, the privilege of *ubiquity* pertaining to peridot, as well in our deep subjacent rocks as in the meteorites, is explained, as the preceding experiments show, by the fact that it is in some sort the *universal scoria*.

It may be concluded from what precedes that oxygen, so essential to organic nature, must also have played an important part in the formation of the planetary bodies. Let us add that without oxygen we can conceive of no ocean, nor of any of those great functions, whether superficial or profound, of which water is the cause.

We thus touch on the foundations of the history of the globe, and draw closer the bonds of relationship, already disclosed by the similarity of their composition, between the parts of the universe whose nature it is given us to know.

APPENDIX.

DEVELOPMENT OF THE COLLECTION OF METEORITES OF THE MUSEUM.

For the thorough study of meteorites it was indispensable to possess a collection in which the descents which have occurred in different countries should be represented in as complete a manner as possible, and in which they might be examined and compared with one another. For this reason it is proper to say a few words on the development of the principal collection of France.

Specimens of divers meteoric descents had already been annexed to the museum. With a view of developing this rising collection, I made an appeal, which has been heard in Europe and in different other regions of the globe, by numerous persons desirous of promoting science. In 1861 the specimens, representing 53 falls, amounted in number to 86, weighing altogether 691 kilograms. On the 30th of March, 1868, at which time a new and detailed catalogue was published, the number of falls represented, embracing the discoveries of meteorites of incontestable origin but unascertained date, was 203; the number of the specimens exceeded 550, and formed a weight of 1,682 kilograms.

This collection, arranged at first in chronological order, has recently been classified methodically, in conformity with the principles of classification given above.

CATALOGUE OF METEORITES IN THE MINERALOGICAL COLLECTION OF YALE COLLEGE.

Stony meteorites.

No.	Time of fall.	Locality.	Weight in grams.
1	Nov. 7, 1492	Ensisheim, France	*28
2	Dec. 13, 1798	Benares, (India)	1
3	Apr. 26, 1803	L'Aigle, France	902
4	Dec. 14, 1807	Weston, Connecticut	*17,300
5	Apr. 19, 1808	Borgo San Donino, (Parma,) Italy	10
6	May 22, 1808	Stannern, Moravia	*134
7	Nov. 23, 1810	Charsonville, France	9
8	July 8, 1811	Berlanguillas, Spain	14
8a	Apr. 15, 1812	Erxleben, Prussia	13
9	Aug. 5, 1812	Chantonnay, France	*42
10	Feb. 15, 1814	Bachmut, Russia	2
11	Feb. 18, 1815	Durala, India	3
12	Aug. 10, 1818	Slobodka, Russia	2
13	June 13, 1819	Jonzac, France	2
14	Nov. 30, 1822	Futtehpur, (Allahabad,) India	36
15	1822–'23	Umballa, India	1
16	Feb. 10, 1825	Nanjemoy, Maryland	897
17	Sept. 14, 1825	Honolulu, Sandwich islands	*617
18	May 9, 1827	Nashville, (Drake Creek,) Tennessee	425
19	June 4, 1828	Richmond, Virginia	*311
20	May 8, 1829	Forsyth, Georgia	141
21	July 18, 1831	Vouillé, France	5
22	Apr. 18, 1838	Akburpur, India	1
23	June 6, 1838	Chandakapoor, India	41
24	Oct. 13, 1838	Cold-Bokkeweld, Africa	143
25	Feb. 13, 1839	Pine Bluff, (Little Piney,) Missouri	24
26	June 12, 1841	Château-Renard, France	91
27	June 2, 1843	Utrecht, Holland	4
28	Mar. 25, 1843	Bishopville, South Carolina	213
29	May 8, 1846	Macerata, Italy	3
30	Feb. 25, 1847	Linn county, Iowa	*651
31	Oct. 31, 1849	Cabarras county, (Charlotte,) North Carolina	231
32	Nov. 30, 1850	Shalka, Bengal	1
33	Apr. 17, 1851	Gutersloh, Westphalia	4
34	Jan. 22, 1852	Yatoor, (Nellore,) India	*47
35	Sept. 4, 1852	Mezö Madaras, Hungary	20
36	Mar. 6, 1853	Segowlee, Bengal	46
37	May 13, 1855	Island of Oesel, Livonia	6
38	Feb. 28, 1857	Parnallee, India	2,371
39	Mar. 26, 1859	Harrison county, Kentucky	17
40	May 1, 1860	New Concord, (Guernsey county,) Ohio	7,000
41	May 12, 1861	Qutahar Bazaar, India	92
42	June 2, 1863	Buschof, Russia	22
43	Aug. 8, 1863	Pillister, Russia	*16
44	Aug. 12, 1864	Nerft, Russia	48
45	Jan. 30, 1868	Pultusk, Poland	*365
46	Dec. 5, 1868	Frankfort, (Franklin county,) Alabama	

Iron meteorites.

(With date of discovery or description.)

No.	Time of fall.	Locality.	Weight in grams.
1	1751, May 26	Hraschina, (Agram,) Austria	3
2	1751	Steinbach, Saxony	2
3	1749	Krasnojarsk, (Pallas-iron,) Siberia	*1,926
4	1784	Xiquipilco, (Toluca,) Mexico	*900
5	1801	Cape of Good Hope, South Africa	*12
6	1808, (1814)	Red river, Texas	740,000
7	1811	Elbogen, Bohemia	8
8	1814	Bitburg, Eifel	*63
9	1814, (1815)	Lenarto, Hungary	120
10	1818	Lockport, (Cambria,) New York	3,154
11	1819	Burlington, (Otsego county,) New York	740
12	1820	Guilford county, North Carolina	20
13	1827	Atacama	83
14	1829	Bohumilitz, Bohemia	37
15	1834	Claiborne county, Alabama	74
16	1839	Putnam county, Georgia	*382
17	1840	Cocke county, (Sevier,) Tennessee	*1,080
18	1840	Arva, (Szlanicza,) Hungary	*1,237
19	1841	Scriba, (Oswego county,) New York	281
20	1845	Asheville, (Black Mount.,) North Carolina	15
21	1845	De Kalb county, (Caryfort,) Tennessee	61
22	1845	St. Augustine's bay, Madagascar	7
23	1845	Walker county, Alabama	356
24	1846	Carthage, (Smith county,) Tennessee	104
25	1847	Seeläsgen, Prussia	174
26	1849	Pittsburg, Pennsylvania	253
27	1849	Chesterville, (Chester county,) South Carolina	757
28	1850	Schwetz, Prussia	256
29	1850	Salt river, Kentucky	1,384
30	1850	Ruff's mountain, (Lexington co.,) North Carolina	536
31	1850	Seneca river, New York	*437
32	1850	Niokarnak, West Greenland	141
33	1853	Lion river, South Africa	40
34	1853	Tazewell, (Claiborne county,) Tennessee	418
35	1854	Madoc, Canada West	26
36	1854	Octibbeha county, Mississippi	1
37	1854	Tucson, Arizona	158
38	1854	Hainholz, Westphalia	8
39	1854	Orange river, South Africa	27
40	1856	Nelson county, Kentucky	112
41	1856	Madison county, North Carolina	45
42	1856	Denton county, Texas	66
43	1856	Fort St. Pierre	344
44	1861	Newstead, Scotland	96
45	1861	Robertson county, Tennessee	115
46	1862	Colorado river, near La Paz	11
47		Southeast Missouri	68
48		Dakota	
49		Near Chihuahua, Mexico	51
50		Mexico, (Poinsett meteorite)	
51		Columbia, South America	57
52	1867	Arizona, (iron and olivine)	42
53		Colorado Territory	157
54	1860	Franklin county, Kentucky	37
55		Russell's Gulch, Colorado	120
56		Australia, (crust)	104

The total number of stone falls represented is 47, of which the largest specimen in the collection is one which fell at Weston, Connecticut, December 14, 1807, weighing 36½ pounds, (16½ kilos.) The number of iron localities is 56; the

largest iron meteorite is that from the Red river, in Texas, found in 1808, weighing 1,635 pounds, (740 kilos.) The collection also contains several specimens not enumerated in the catalogue of questionable meteoric origin, such as the silicate from Concord, New Hampshire, the iron from Hommoney creek, and others. The so-called native iron of Canaan, Connecticut, long since shown to be a furnace product, is also preserved in the museum.

It is desired to increase the number of specimens and localities represented in this collection, and for this purpose persons having knowledge of specimens or facts connected therewith are solicited to communicate with Professor H. A. Newton or Professor G. J. Brush, who are specially interested in the investigation of the astronomical, chemical, and mineralogical relations of these interesting bodies. Specimens marked with an asterisk are in duplicate.

GEO. J. BRUSH,
Curator of the Mineralogical Collection of Yale College.

YALE COLLEGE, NEW HAVEN, CONN.,
March 1, 1869.

OBSERVATIONS ON THE ELECTRIC RESONANCE (BOURDONNEMENT) OF MOUNTAINS.*

BY M. HENRI DE SAUSSURE.

[*Translated for the Smithsonian Institution.*]

Leaving Saint-Moritz (Grisons) June 22, 1865, I made an ascension of the Piz Surley, a mountain composed of crystalline rocks, whose summit, more or less conic, attains an altitude of 3,200 meters.

During the previous days the north wind had constantly prevailed; on the 22d the wind became variable, and the sky was charged with floating clouds. Towards midday these vapors augmented and gathered in masses above the highest summits, sustaining themselves, however, at such an elevation as not to veil most of the spires and peaks of the Engadine, on which fell soon some local showers. Their aspect of *powdery vapors*, semi-transparent, caused us to take them for mere squalls of snow or sleet.

In effect, towards one in the afternoon, we were ourselves assailed by a fine and thin sleet, at the same time that similar squalls enveloped most of the spires of rock, such as the Piz Ot, Piz Julier, Piz Langard, &c., and the snowy summits of the Bernina, while a voilent fall of rain descended on the valley of Saint-Moritz.

The cold increased, and half an hour later, when we had arrived at the top of the Piz Surley, the fall of sleet becoming more abundant, we disposed ourselves to take a repast, and leaned our staves against a small pyramid of dry stones which crowns the summit of the mountain. Almost at the same instant I experienced in the back, at the left shoulder, a piercing pain, like that which would be produced by a pin slowly driven into the flesh, and when I applied the hand to the place without finding anything there, similar pain was felt in the right shoulder. Supposing that my linen overcoat contained pins, I threw it off; but, far from finding relief, I perceived that the pains augmented, invading the whole back from shoulder to shoulder; they were accompanied by tickling, by distressing twinges, such as would be produced by a wasp which was creeping over the skin and piercing me with stings. Hastily removing my second coat, I discovered nothing of a nature to wound the flesh. The pain, which still continued, then assumed the character of a burn. Without reflecting, I imagined that my woolen shirt, though I could not tell how, had taken fire, and I was going to throw off the rest of my apparel, when our attention was attracted by a noise which resembled the humming of large insects. This proceeded from our three staves, which, inclined against the rock, were *chanting* loudly, giving out a whistling sound analogous to that of a kettle, the water of which is on the point of entering into ebullition. All this may have occupied four or five minutes.

I comprehended, on the instant, that my painful sensations proceeded from an intense electrical efflux which was taking place from the summit of the mountain. Some extemporized experiments on our staves yielded no appearance of any spark nor any light appreciable by day; they vibrated with force in the hand

* The observations which follow had been communicated by correspondence to M. J. Fournet, who has introduced them in his notices on *Electric Regions*, published in the *Comptes Rendus de l'Académie des Sciences*, tome xliv, 1867. We give them here with some modifications and considered in a more special point of view.

and gave a very distinct sound; whether held in a vertical position, with the iron point above or below, or in a horizontal one, the vibrations remained the same, but no sound escaped from the surface of the ground.

The sky had become gray over its whole extent, although unequally charged with clouds. Some minutes afterwards I felt the hairs of my head and face stand on end, imparting a sensation analogous to that of a razor passed when dry through a stiff beard. A young Frenchman, who accompanied me, exclaimed that he felt a sensation in every particular hair of his incipient moustache, and that strong currents were issuing from the tips of his ears. On lifting my hand I felt currents quite as distinctly escaping from my fingers. In short, a strong electricity was flowing from staves, clothes, ears, hair, and from all the salient parts of our bodies.

A single explosion of thunder was now heard towards the west in the distance. We quitted the peak of the mountain with some precipitation, and descended about 100 meters. In proportion as we proceeded our staves vibrated less and less strongly, and we stopped when their sound had become so feeble as to be no longer perceptible except on bringing them close to the ear. The pain in the back had ceased with the first steps of the descent, but I still retained a certain vague impression of it.

Ten minutes after the first, a second reverberation of thunder was heard to the west at a great distance, and these were all. No lightning was seen. Half an hour after we had left the summit the sleet had ceased, the clouds broke away, and at 30 minutes after two we again reached the topmost point of the Piz Surley, there to find sunshine.

We judged that the same phenomenon must have been produced on all the peaks formed by projecting rocks, for all, like that which we occupied, were enveloped in whirls of sleet, while no condensation showed itself in the rest of the sky; and the great snowy summits of the Bernina, to which clung groups of clouds, seemed also exempt from it. But, the same day, a violent storm burst upon the Bernese Alps, where an English lady was struck by lightning. On the horizon, divers peaks, especially the sharpest, such as the Piz Ot and the Piz Languard, continued to be enveloped by sleety whirls, even when the sky had everywhere begun to grow blue.

I had been the witness of another case of the efflux of electricity from the summit of mountains when I visited, some years ago, the Nevado de Toluca, in Mexico; but there the phenomenon had still more intensity, as might be expected, since it occurred under the tropics, at an altitude of about 4,500 meters. I may be allowed to cite here what I have elsewhere said of it.*

In the month of August, 1856, I made, with M. Peyrot, the ascent of the Nevado de Toluca; it was in the midst of the rainy season, and there was some degree of imprudence in attempting the expedition at that time. We attained the summit without any menacing appearance of the skies, though cumuli were to be seen here and there, and from time to time fogs settled on the needles of rocks which spring aloft from the crest of the mountain. We rested on the border of the crater to recover our strength and enjoy for a moment the grand spectacle which unfolded itself at our feet. From the height of the edge the eye plunged into that immense amphitheater, whose focus, long extinct, is now occupied by two small lakes, towards which we were preparing to descend. A cold and disagreeable wind arose from this gulf, and, while we were taking a slight repast, we saw a thick cloud penetrate into the crater by its southeast notch and ascend towards us, eddying around the walls of the amphitheater. Presently we were enveloped in a glacial fog. Surprised by this threatening symptom, we saw that we had not an instant to lose if we wished to visit the crater, and I commenced clambering down over the rubbish which leads to the

* *Coup d'œil sur l'hydrologie du Mexique*, 1 part, (note. A)

bottom of the abyss. But scarcely had I reached half way when the storm, bursting forth with astonishing suddenness, obliged me to reascend as soon as possible towards the point I had left.

There was at first a fine rain, then small hail, driven by a violent wind. In a moment the mountain became white and the cold intense. The bursts of thunder, at first interrupted, soon seemed to roll without cessation and with fearful crashes, especially when they issued from the circuit of the crater, into which darted, at frequent intervals, flashes of lightning. Without shelter in the midst of these naked rocks, without even a block behind which to cower, nothing remained for us but to sit down on the earth with backs turned to the hail. After the lapse of some time the cold became insupportable, and the dread with which the tempest had inspired us drove us from the summit, though our observations were unfinished. While we descended rapidly the rocks of the Nevado, rain for an instant succeeded the hail, and as we coasted a small stony ravine,* formed by ancient outcrops of trachyte, and where the vegetation of shrubs commences, the storm seemed momentarily to subside. The thunder ceased or drew off to a distance, but we presently saw a grayish cloud advance, which enveloped us during its passage, and *was accompanied with sleet.* Immediately the hair of our Indian attendants was observed to be in agitation as if about to stand erect, and we experienced various electrical sensations in the beard and ears. Next a dull, undefinable noise was heard, at first feeble though general, but presently stronger and perfectly distinct. There was a universal crepitation, as though the small stones of the whole mountain were clashing against one another. Our terrified Indians gave free vent to their superstition in words, and it cannot be denied that there was something disquieting in the sounds which then prevailed in the mountain. This phenomenon lasted five or six minutes, and then the rain and thunder again commenced in full force. The storm became more supportable when we had descended to the upper limit of the forests, although one of those diluvial rains was falling which characterize the hot season under the tropics.

M. F. Craveri, an Italian physicist, settled at Mexico, who, before myself, had made an ascent of the Nevado de Toluca at the commencement of the rainy season, recounted to me that he had been a witness of the same facts, which he could not recall without an impression of terror. The electric state was still more violent. The traveler in question ascended the mountain May 19, 1845, by the southeast side, starting from Tenango, and descended by the northwest slope to Toluca. The southwest side was at that season destitute of snow. The electric phenomenon was suddenly brought on by a cloud arriving from the west, and which had perhaps taken its rise on the fields of snow of that side. Scarcely were the travelers enveloped in it when they experienced the sensation which electricity produces, and this was almost immediately followed by a dull noise. They felt irregular currents of electricity at all their extremities, the fingers, the ears, the nose. The fear which seized them in the midst of these lofty solitudes impelled them at once to commence their descent at a precipitate pace. The thunder did not yet resound, but at the end of five minutes *there fell a snow resembling rice*, and the cloud communicating its electricity to the ground, the same noise arose therefrom which I have indicated above. This noise was very intense and seemed general in all the mountain. The long hair of the Indians became stiff and erect, giving to their heads an enormous magnitude. The sight of this phenomenon added to the panic terrors of the excursionists, who had counted upon finding nothing but pleasure in the adventure.

The very singular noise which makes itself heard in the rocks of the mountains at the moment of the electric phenomenon deserves to be studied by competent physicists. It resembles the rattling sound which pebbles would produce if

* For greater precision I have modified this passage, having written in my former notice: "as we followed a stony valley." There was, in fact, but a slight depression of the soil, whence the word "valley" says too much and might be misunderstood.

struck against one another on being alternately attracted and repelled by electricity; but it appears to me to proceed unquestionably from a sort of crepitation or crackling of electricity escaping through the asperities of the stony surface.

A third observation of the same kind we owe to M. Craveri, who was surprised by the same meteor near the summit of Popocatepetl, September 15, 1855, with this difference, that the incident taking place on fields of snow, the noise of the crepitation of the ground was not produced.

The following are the analogous facts which have come to my knowledge:

In 1767 H. B. de Saussure visited the top of the Brevent in company with Pictet and Jalabert.* The travelers were there directly electrified to such an extent that on stretching out their hands they experienced prickings at the end of the fingers; the electricity escaped from them with a kind of thrilling sensation. Sparks, it was found, might be drawn from the button of a gold band which surrounded one of their hats, and also from the iron end of a mountain staff. These effects were attributed to a great storm-cloud which occupied the middle region of Mont Blanc, and which gradually extended itself above the Brevent. At a dozen toises below the top of that mountain the electricity was no longer perceived. The storm raged around Mont Blanc, but on the Brevent there fell only a light rain of short duration, and then the disturbance was dissipated. From this recital it is easy to see that the storm did not prevail upon the Brevent at the moment of the observation, since there was no rain falling; but that, at this point, the electricity discharged itself in a continuous current by the summit of the mountain.

In 1863, M. Spence Watson, visiting, with some guides the Col de la Jungfrau, was overtaken by a hurricane, attended with hail and snow. The staves commenced their peculiar *chant;* the expeditionists experienced sensations of heat in different parts of their bodies,† especially the head, and the hair stood erect; a guide took off his hat, exclaiming that his head was burning; a veil was kept stiff and straight in the air. Electric currents, at the same time, escaped at the ends of the fingers. Claps of thunder (in the distance, for no lightning was seen) for an instant interrupted the phenomenon. Finally, shocks were felt, and M. Watson had the right arm paralyzed for some minutes. This arm continued for several hours to be the seat of acute pains.‡ During this time *the snow fell whistling like hail.*§ But what is most remarkable was the emission of a noise by the snow, a crackling similar to that of a brisk shower of hail, evidently the analogue of that which the ground of the Nevado de Toluca emitted in the observation above described. The phenomenon lasted 25 minutes. It had no unpleasant consequence, except a burning in the faces of the travelers as if they had been exposed to the sun on the snow.

M. Forbes, while crossing by St. Theodule, heard the chant of the staves, and, in July, 1856, M. Alizier, of Geneva, witnessed the same phenomenon near the summit of the Oldenhorn, when the sky was overcast and a storm was imminent, which burst forth an hour afterwards and *was mingled with hail.*|| We will not speak of the storm during which Colonel Buchwalder and his aid were struck by lightning on the Sentis, for there the phenomenon was of a different order and falls rather within the category of the thunderbolt.

But the nocturnal illumination of rocks pertains probably to the phenomenon of electric efflux from culminant peaks. M. Fournet cites, on this subject, the striking luminosity of the rocks of the Grands-Mulets (Mont Blanc), observed by M. Blackwall, on the night of August 11, 1854, and which was accompanied

* *Voyage dans les Alpes*, tome ii.

† This sensation of heat seems to me to be of the same kind with the pain which I experienced in the back.

‡ *Alpine Journal*, September, 1863.

§ Probably snow resembling rice, a sleety shower.

|| See the note of M. C. M. Briquet, (*Echo des Alpes*, 1865, No. 4.) *Sur les phénomenes électriques qui accompagnent les orages à des grandes altitudes*, where these observations are collected and compared. Geneva, 1865.

by sparks. On the other hand, the phenomenon of electricity displayed on the lakes, and on the very dry plains of elevated plateaux, does not seem to me of the same nature. Finally, the surprising fact of the so-called galloping electricity, coursing over prairies, observed by M. Quiquerez, near Courtamon, may be regarded as a variety of lightning; a miniature lightning, resulting from the fact that the electrified cloud was grazing the earth and discharged itself over the whole surface by a thousand sparks, which were seen to run along the ground. It is probable that these phenomena should be divided into several categories, the causes of which are not identical. Some proceed from a static tension, others from a series of discharges having a certain analogy to lightning.

The phenomenon of the *chant of batons* or staves, in other words, the resonance or *bourdonnement* of the soil, constitutes still another species. It has been observed only on the summit of mountains or of culminant peaks; never, as far as I know, on plains or at the bottom of valleys. It supposes a continuous dynamic action, or an efflux of the fluid towards the clouds by the most salient terrestrial conductors, sensibly different from static tensions and abrupt discharges.

If we collate the observations which have been above indicated, we shall distinguish therein several common features:

1st. The efflux of electricity by the culminant rocks of mountains is produced under a clouded sky, charged with low clouds, enveloping the summits or passing at a small distance above them, but without the occurrence of electric discharges above the place whence the continuous efflux is proceeding. It would seem, therefore, that when this efflux takes place, it sufficiently relieves the electric tension to prevent lightning from being formed.

2d. In all the cases observed, the summit of the mountain was enveloped by a shower of hail or sleet, which leads to the supposition that the continuous efflux of electricity from the ground towards the clouds is not unconnected with the formation of the vapor and probably also with that of the hail.

At the Piz Surley and at the Nevado de Toluca there fell a sleet or snow resembling rice, and at the pass of the Jungfrau the snow fell *whistling like hail*, which seems to indicate that it was rather sleet which was falling than snow.

Doubtless we should take into account the higher temperature of the valleys, where the hail, proceeding to melt, turns into rain; but still we do not think that in the particular cases which we have just indicated the phenomenon of rain falling in the valley and that of the sleet of the isolated mountain peaks relate to a condensation taking place in accordance with identical laws through the whole extent of the sky. Thus, in particular, during the observation of June 22, 1865, I saw on the horizon all the spires of rocks, although isolated and far remote from one another, enveloped by a powdery sleet which continued for a long time, while in the rest of the sky all condensation had ceased, and in the valley there fell a copious shower of rain, but of very short duration.

Moreover, the phenomenon which passed around the summits of the rocks was quite different from that which deluged the valleys. Around these lofty pyramids there were columns of a fine sleet of great rarity; in the valley a heavy and drenching rain, such as the thin sleet of the summits would not have produced had it been converted into water. Around the elevated projections, therefore, by which the electricity was flowing off, the condensation presented the special character of being little abundant, powdery (fine sleet), and more persistent than in the rest of the sky.

The electric phenomenon which has been described, and which we term the electric resonance of the mountains, seems not to be rare in high regions, without, however, being very frequent. Among the guides and hunters whom I have interrogated on the subject, some had never observed it; others had heard it but once or twice in their lives. But it is proper to add that it is precisely on those days when menacing skies repel adventurers from the highest altitudes that the phenomenon manifests itself.

EXPERIMENTS ON ANEROID BAROMETERS MADE AT THE KEW OBSERVATORY.

By B. Stewart, LL. D., F. R. S.

(From the Proceedings of the Royal Society, London.)

[The frequent use of the aneroid barometer in meteorological observations and in topographical surveys in this country will render the following paper from the proceedings of the Royal Society of London interesting to many of the readers of the Smithsonian Report.—J. H.]

In judging of the value of an instrument, says the report, such as an aneroid, it is not the mere extent of difference between its indications and those of a standard barometer that ought to guide us; but it is rather the constancy of its indications under the various circumstances to which it may be subjected, that determines its value. An aneroid may differ from a standard barometer at the ordinary pressure, and to a greater extent at other pressures; but provided these differences can be well ascertained and remain constant, such an instrument ought to be regarded as valuable, just as much as a chronometer of known constancy, but of which the rate is wrong.

The circumstances which may be supposed to affect the indications of an aneroid may be classed under three heads, namely:

1. Time.
2. Temperature.
3. Sudden variations of pressure.

1. *Time.*—As to the influence of time, no definite experiments were made.

2. *Temperature.*—A good aneroid is generally compensated by its maker for the effects of temperature, and the question to be investigated is, to what extent such compensations are trustworthy. I record the results of subjecting six aneroids, each four and one-half inches in diameter, made by two different makers, to a very considerable range of temperature.

No. of instrument.	Correction at				
	55° F.	72° F.	78° F.	88° F.	100° F.
2	—.105	—.135	—.140	—.145	—.145
3	—.055	—.090	—.095	—.095	—.100
4	—.095	—.095	—.095	—.080	—.060
5	—.106	—.106	—.111	—.111	—.111
6	—.101	—.111	—.111	—.106	—.106
7	—.061	—.061	—.061	—.061	—.031

These results are, on the whole, very satisfactory, and appear to show that a well-made compensated instrument has its indications comparatively little affected by a very considerable temperature change. It ought always to be borne in mind that an aneroid is not capable of being read to the same accuracy as a standard barometer, and that the 1-100th of an inch is a very small quantity. These temperature experiments were made at the ordinary atmospheric pressure. I am unable to say what effect a change of temperature would have at a diminished pressure.

3. *Sudden changes of pressure.*—For the purpose of investigating the influence of sudden changes of pressure upon the indications of aneroids, I applied to some of the best-known makers of these instruments for the loan of several, and through their courtesy in lending me a sufficient number, and for a sufficiently long time, I have been enabled to investigate this influence at some length. In the following experiments the instruments were, to begin with, suspended vertically, at the usual atmospheric pressure. They were tapped before being read. The pressure was then lowered an inch, and the instrument allowed to remain 10 minutes at this pressure before being read, after having been again well tapped. The pressure was thus reduced an inch every time, being allowed to remain 10 minutes at each stage; the instrument was always well tapped before being read, by means of an arrangement contrived for this purpose by Mr. R. Beckley. The exhaustion was carried downwards to 19 inches, and the instrument was allowed to remain an hour and a half at its lowest pressure; the air was then admitted an inch at a time, the previous arrangement as to time and tapping being followed.

Separating the results of the experiments into two sets, one comprising large (four inch to four and a half inch) aneroids, and the other small instruments, we find the mean down correction to be as follows, each aneroid being supposed right at 29 inches:

	29 in.	28 in.	27 in.	26 in.	25 in.	24 in.	23 in.	22 in.	21 in.	20 in.	19 in.
Mean correction of two large aneroids	.00	.00	+.02	+.03	+.04	+.04	+.07	+.11	+.14	+.19	+.25
Mean correction for four small aneroids	.00	+.01	+.02	+.03	+.07	+.07	+.09	+.12	+.17	+.23	+.25

We see from these results, says Dr. Stewart, that if aneroids, right to begin with, be subjected to a decrease of pressure similar to that to which they were subjected in these experiments—

1. That a well-constructed large aneroid will not go far wrong down to 24 inches, but after that pressure its reading will be considerably lower than that of a standard barometer, so that a large positive correction will have to be applied.

2. That small aneroids are less trustworthy than large ones, and probably cannot be trusted below 26 inches.

3. That if previous experiments are made upon an aneroid, we are enabled by this means to obtain a table of corrections which, when applied to future observations with the same instrument, will most probably present us with a much better result than had we not verified our instrument at all, and that by this means we may use our instrument down to 19 inches with very good results.

Readings of these instruments under increasing pressure, after remaining an hour and a half at the lowest reading, were recorded.

The mean corrections for up readings are exhibited in the following table, each aneroid being supposed right at 19 inches:

	19 in.	20 in.	21 in.	22 in.	23 in.	24 in.	25 in.	26 in.	27 in.	28 in.	29 in.	30 in.
For two large aneroids	.00	+.03	+.03	+.03	+.03	+.02	+.01	.00	—.03	—.06	—.08	—.11
For four small aneroids	.00	.00	+.01	+.02	—.01	—.01	—.02	—.04	—.07	—.10	—.15	—.16

We may learn from these results, says Dr. Stewart, that if aneroids which have been subjected for at least one hour and a half to the lowest pressures which they register, have the pressure increased by means of the gradual introduction of air into the receiver, after the manner already described—

1. That a well-constructed large aneroid will not go far wrong for about 8 inches above the lowest pressure.

2. That in this respect small aneroids are somewhat less trustworthy than large ones.

3. That if the instrument read be previously tested and its corrections ascertained, we may consider it trustworthy (making use of these corrections) for up readings throughout a greater range than if it had not been so tested.

I come now to consider whether a rapid change of pressure affects an aneroid after the experiment has been completed.

The following table will exhibit the results obtained in this direction:

	Aneroid No.				
	8.	9.	10.	14.	16.
Correction before experiment	—.10	—.12	—.12	—.04	—.05
Immediately after experiment	.00	+.03	+.06	+.06	+.04
Eighteen hours after experiment	—.07	—.03	......	—.01	+.01
Forty-eight hours after experiment	—.08	—.04	—.03	......	......
Three days after experiment	—.08	—.05	......	—.01	—.01
Three weeks after experiment	—.13	—.10	—.11	—.07	—.06

It thus appears that if an instrument reads correctly before it is put into the receiver it will read too low immediately afterwards, and that it may be some considerable time before it recovers its previous reading. The instrument cannot, therefore, be safely trusted for absolute determinations if it has been recently exposed to rapid changes of pressure.

The experiments hitherto recorded, in which an inch of pressure has been taken away or added every 10 minutes, are perhaps analogous to ascents in a balloon, or descents from a mountain; they are not, however, precisely analogous to mountain ascents, since a longer time than 10 minutes is usually taken to produce a change of pressure equal to one inch.

At the suggestion of Mr. Charles Brooke, a couple of aneroids were tested in April, 1868, with the view of rendering the experiment more analogous to a mountain ascent.

The pressure was reduced by half an inch at a time, and at intervals of 30 minutes, the aneroids being well tapped.

The following corrections were obtained for down readings, (instruments supposed right at 30 inches:)

At	No. 8.	No. 9.	At	No. 8.	No. 9.
Inches.			*Inches.*		
30	.00	.00	24	+.05	—.01
29.5	.00	—.03	23.5	+.08	—.02
29	.00	—.04	23	+.11	—.03
28.5	.00	—.03	22.5	+.12	—.01
28	.00	—.03	22	+.14	.00
27.5	.00	—.02	21.5	+.16	+.02
27	...	.....	21	+.17	+.04
26.5	.00	—.02	20.5	+.20	+.06
26	+.01	—.02	20	+.22	+.07
25.5	+.04	—.02	19.5	+.25	+.09
25	+.05	—.04	19	+.27	+.11
24.5	+.06	—.02			

These results, when compared with the previous determinations for these same instruments, would seem to show that a somewhat better result is obtained when the exhaustion is carried on more slowly, and hence that the corrections depend, to a considerable extent, on the nature of the treatment received.

From all these experiments, Dr. Stewart concludes as follows:

A good aneroid of large size may be corrected for temperature by an optician, so that the residual correction shall be very small.

If an aneroid, correct to commence with, be used for a balloon or mountain ascent, it will be tolerably correct for a decrease of about six inches of pressure.

A large aneroid is more likely to be correct than a small one.

The range of correctness of an instrument used for mountain ascents may be increased by a previous verification, a table of corrections being thus obtained.

If an aneroid has remained some time at the top of a mountain, and be supposed correct to start with, then it will give good results for about eight inches of increase of pressure.

A large aneroid is more likely to be correct than a small one

If the aneroid has been previously verified, it is likely to give a better result.

After being subjected to sudden changes of pressure, the zero of an aneroid gradually changes, so that under such circumstances it ought only to be used as a differential and not as an absolute instrument, that is to say, used to determine the distance ascended, making it correct to begin with, or to ascertain the distance descended, making it correct to begin with, it being understood that the instrument ought to be quiescent for some time before the change of pressure is made.

[I have subjected many aneroids to the test of a sudden diminution of pressure under the receivers of an air-pump, but have never found one of which the index would return to the same point when the original pressure was restored. I have not, however, had recourse to tapping, which Mr. Stewart has found essential. The instrument in its present condition cannot be relied on to indicate absolute pressure, though it may be used in many cases with good effect in determining differences of pressure of limited extent.—J. H.]

ANNIVERSARY ADDRESS.

OF THE

PRESIDENT OF THE ROYAL SOCIETY OF VICTORIA.

By R. L. J. Ellery.*

Gentlemen of the Royal Society of Victoria: For the third time it devolves upon me as your President to deliver the annual address on this occasion, inaugurating our 13th session.

The honor you have thus conferred upon me was, I confess, an unexpected one; I beg, however, to assure you most earnestly that I am fully sensible of the distinction implied in your trust, and no less of the responsibility which it entails.

On similar occasions it has been our custom to review the society's operations during the previous session, touching, also, on the scientific progress of our public scientific institutions during the past year. Adopting our usual plan, I now propose to briefly review, first, the contributions laid before you at your various meetings during your last session, following this by a general survey of the year's history of our scientific departments, and concluding with a brief notice of one or two of the more salient points of scientific discovery belonging to the year 1867; for the scientific institutions of the colony derive so much strength and direction from the work done at the older centres of learning that no review of our progress is, I conceive, adequately represented without some reference to the general progress of human knowledge.

If, in referring to the work of our past session, I appear to dwell unduly upon some of the subjects which have occupied your attention, I ask you to follow me in regarding them as of more than usual interest and importance, and on that account claiming a more detailed consideration.

During our last session we held 11 ordinary meetings. The papers and the discussions following the reading of them were generally of great interest and importance, doubtless aiding us in our advance in the departments of knowledge to which they belong. By the indefatigable zeal of your honorary secretary, Mr. Thomas H. Rawlings, the whole of the last year's transactions have been printed, and were placed in your hands shortly after the close of the year, and also distributed to the various learned societies with which we are in communication.

Of the contributions laid before you, two pertain to physical science, three to the natural history of Australia, three to the development of our natural resources, two to pathological science, four to the geology, mineralogy, and palæontology of Australia and New Zealand, one to social science, and two to applied chemistry.

I will first refer to the Rev. J. E. Tenison Wood's paper "On the Glacial Period of Australia," in which he gives his reasons for concluding that "during the glacial period of Europe our continent and seas have passed through a subtropical climate," or at least a much warmer one than we now experience. He stated, as you well remember, that he did not base his opinion upon the absence of those groovings and striations left by the mighty slip of glaciers and icebergs—for in the northern hemisphere these are not found lower than the 40th parallel

* From the Transactions of the Royal Society of Victoria, part 1, vol. 9, July, 1868.

of latitude—but rather upon the subtropical character of our tertiary fauna. He concluded his paper by saying, "A true glacial epoch in New Zealand would be a puzzling fact, and very difficult to reconcile with what we see in Australia," and stating his belief that the Australian continent is now passing through a colder period than any of which we can find evidence in its previous geological history. On the same subject, and discussing these views, Dr. Haast, an honorary member of this society and geologist to the province of Canterbury, New Zealand, contributed a paper which was read at the October meeting. Referring to Mr. Wood's paper, he stated that he had traced glacial action over the whole length and breadth of the south island of New Zealand; he does not accept Mr. Wood's conclusion with respect to the non-existence of evidence indicative of our continent having passed through a glacial period, and points out that if geologists want to find traces of this epoch they must look for it in the Australian alps, where morainic accumulation may have been preserved around the lakes; but from the small altitude of this chain he expects these will be of small extent and dimensions.

Mr. Thompson read a paper "On the Formation of Mineral Veins and the Deposit of Metallic Ores and Metals in them," at our October meeting. In the present stage of our knowledge of geological changes, the mode of occurrence of minerals in veins, and the formation of the latter, present almost insuperable difficulties to the clear comprehension of them. This subject, although it has taxed the energies of Hopkins, Bischoff, and other superior minds, may be considered as still unsolved. In Mr. Thompson's paper, his conclusions are based upon observations of particular cases, and are thus preferable to geological conceptions of a purely speculative character.

Professor McCoy, at the February meeting, announced the discovery in Australia of *Enaliosauria* and other cretaceous fossils, thus establishing the fact—of immense geological importance—of the existence of the cretaceous period on the Australian continent.

A description of a fine specimen of rubellite or red tourmalin, found for the first time in Victoria in a mine at Maldon, was read by the Rev. Dr. Bleasdale, at our July meeting.

An account of some bone-caves at Glenorchy, in Tasmania, contributed by Mr. Wintle, of Hobart Town, was also read on the same evening.

Turning to the papers having reference to natural history. At the first meeting of the session Professor McCoy described three new species of Victorian birds, and at the September meeting he contributed a paper "On the species of Wombats," in which he showed us that until very recently only one species of wombat was known to zoologists, the *Phascolomys wombat*, but that the existence of four species, which he described, may now be considered as demonstrated.

At the meeting in May an elaborate paper "On the Australian Coleoptera" was presented to the society by that renowned naturalist, Count de Castlenau. It contains descriptions of a large number of new Australian beetles, and forms a most valuable contribution to entomological science.

Of the two papers which I have classed as pertaining to physical science, one was read at the February meeting by Mr. G. W. Groves, and was entitled "Contributions to Meteorology." The other was a description of a new self-registering electrometer, which I had the honor of reading at the last meeting of the session. This description referred to an apparatus I had devised and erected at the observatory for the purpose of obtaining a continuous record, by the help of photography, of the force and variations of atmospheric electricity. Specimens of the photographic curves it produced were also exhibited. You will be glad to hear that after experience of its performance we have every reason to consider it a most useful addition to the meteorological appliances of the observatory.

Some valuable contributions, bearing on the development of our natural resources, were read at the April, May, and October meetings, the first of which

is "On the Manufacture of Paper from Native Plants," by Mr. Newbery, in which he drew our attention to the importance to be attached to the discovery of raw material suited to paper-making, and pointed out that we had several indigenous plants fitted for this purpose growing in considerable profusion on our waste lands; he especially called attention to two grasses, the *Xerotes longifolia* and a variety of *Lepidosperma*, the fibre of both of which he believed would be of great value for making common paper, and for mixing with rags for white paper. Mr. Newbery's valuable suggestion will, no doubt, be practically tested so soon as the new paper mills on the Yara commence operations.

The second communication of this class was a paper "On Colonial Wines," by the Rev. Mr. Bleasdale. This placed before you a large amount of practical information respecting our vineyards and the wines produced from them. He gave the results of his chemical inquiries into several samples, and indicated the conditions on which he considered the success of Australian wine-making to depend.

Mr. Newbery's paper "On the Analysis of our Mineral Waters" forms another contribution bearing on our natural resources. The writer gives the analysis he has made of the waters from several of our quartz mines remarkable for containing a large percentage of chloride of potassium, as well as of the Ballan springs, the latter found to contain a large percentage of carbonate of soda, with carbonate of lime and magnesia, with 416 cubic inches per gallon of free carbonic acid. This water, as you are aware, has now come into extensive use under the name of "Ballan Seltzer Water;" it forms a very refreshing and pleasant beverage, and may, no doubt, be medicinally useful in some cases.

At the June meeting Professor Halford brought before us his paper "On the Appearances of the Blood after Death by Snake Poisoning." At the October meeting, also, he contributed some further observations on the same subject.

You will remember that in April last, a gentleman died in Melbourne from the bite of a cobra-di-capella, which he had brought from India, and thought to be fangless. At the *post mortem* examination Professor Halford, remarking the great fluidity of the blood, examined some under the microscope, when it appeared to him to contain a great number of colorless cells of a larger size than any usually seen in blood. Further examination corroborated this fact; he observed numerous cells much larger than blood corpuscles, with delicate translucent cell-walls, each cell containing one, two, or more nuclei, and also noted a peculiar macula or nipple on the cell wall after the application of magenta dye. He killed a dog with poison taken from the glands of the same cobra, and other animals with poison taken from Australian snakes, and after death in every case the blood was found fluid and full of these cells. By later observations he was led to believe that the growth of these cells commences immediately the poison gets into the blood, and continues to grow even after death; so that 12 hours after death blood taken from an animal that died from the poison in 10 minutes will be in the same stage as regards the cell growth as that taken one hour after death from an animal that survived the poison 11 hours.

Considering the importance of this subject, I make no apology for troubling you with a succinct account of my personal experience concerning Professor Halford's discovery. Some little time since I had, in company with a friend, a good observer with the microscope, an opportunity of witnessing the progress of this cell growth. A dog bitten by an Australian tiger snake at 9 a. m. died in an hour; at 3 o'clock some blood taken from a vein was dark and quite fluid. Under the microscope the red and white corpuscles appeared normal in size and shape, but were moving about free in the fluid *liquor sanguinis*, and not sticking together in rouleaus, as is usual with healthy blood. Among these corpuscles we observed spaces where some apparently structureless granular matter had pushed them aside. An hour after a fresh supply of blood from another vein showed us, among what appeared to be the same kind of granular matter, large

nucleated cells, which we estimated to be from three to four times the diameter of the ordinary red corpuscle; these cells, whose walls were so delicate and translucent that it required most careful management of the light for their definition, contained nuclei, some one, many with two, three, or even more; delicate as they were, however, they became as distinct as the ordinary red corpuscle by the application of a little magenta dye, which did not seem to alter their dimensions in the least by osmotic action. In many of these cells, also, the little macula on the cell wall was observed, but not on all. In blood taken from the jugular vein 24 hours after death we observed these cells, now appearing more tense, in immense numbers, and many of the nuclei floating about free, as well as a great quantity of transparent acicular crystals, which magenta dye rendered very distinct.

The existence of cells in the blood of the individual who died from the cobra's poison different from those found in cases of pyæmia, leucocythæmia, and other diseases, was warmly contested in this society, and you will remember the animated discussions we had on the subject; but those who have carefully observed the blood in snake-poisoned individuals cannot, I should imagine, be in the least doubt as to the fact of the presence of these cells. My friend and I were very sceptical on this point, and at first failed to see them, but afterwards we felt no longer any question in our minds either as to their presence or to their size being greater than that of any cells in the blood we had ever witnessed or seen described.

Whether this particular cell growth is peculiar to snake-poisoned blood, or whether it may be found in the blood after death from other causes, especially in cases where the blood remains fluid, is a question not yet determined, but one that still occupies Professor Halford's attention, and one to which he invites the general attention of microscopists as well worthy of a searching inquiry. He tells us that in most careful observations, repeated very many times, he traces the growth of the cell out of the germinal matter before alluded to; that first the nucleus appears, then the cell wall. This, if established, is an important point, and one upon which many of our greatest physiologists are not agreed. Kölliker and Virchow holding the view that all cell growth proceeds from preexisting cells, while Schleiden and Schwann believed they always grew out of structureless granular matter; Beale, a later authority, working with higher microscopic powers, leans also to this latter view.

Professor Halford considers that snake poison acts as a kind of ferment in the blood, and that the oxygen which is required to keep it in a condition to support vitality is used up by the cell growth, thereby causing the death of the bitten individual. After death we find the dark fluid blood rapidly absorbs oxygen when exposed to the air, and becomes bright in color; the fibrine has also disappeared, or at all events has become so far degraded by some molecular change as to be no longer coagulable.

Although we may regard these investigations as of the highest importance, not only in their direct reference to the question of snake poisoning and animal poisons generally, as well as to that cell growth and the study of the chemistry and physiology of the blood, yet it must be confessed that the great question of saving from death those bitten by snakes is still an unsolved problem; the light thrown upon the whole subject, however, appears to indicate a path by which the rational treatment of these cases may be arrived at. But little, after all, is known of the functions of the blood or of its connection with nutrition of the tissues and vital force, or of its intricate, chemical, and physical changes in disease; and it is from inquiries of this kind, philosophically conducted, that we must look for progress in this most difficult, and at present obscure, branch of human knowledge. Such inquiries, however, for their successful pursuit, appear to require not only a knowledge of physiology and pathology, but of the highest chemistry and physics generally, a rare combination to be met with in one individual; and

it suggests at once that scientific progress in the treatment of disease will come but slowly, until natural philosophy and chemistry, especially in its dynamical aspect, form as large a part of a medical student's training as even anatomy itself.

Mr. Rusden's paper "On the Ethics of Opinion," was read at the September meeting; it treated of how far men are properly liable to blame or praise, reward or punishment, for their thoughts or actions. The novelty of character of this contribution may have given rise to an impression that it was not exactly of a nature included within the objects of the society; very little consideration must, however, show that any attempt to contribute to social improvement, so long as it is regarded in its scientific aspect, may be fairly considered to come within the scope of this society.

"The Danger of Collision between Vessels crossing one another's Tracks," was the title of a communication from Captain Perry, read to you at the November meeting. In this paper a very simple method of procedure to be adopted by approaching vessels was suggested by the writer, by which danger of collision might, in nearly all cases, be avoided. The plan suggested consists in the approaching ships ascertaining if the same relative bearings between them continues to be maintained, and if so, to alter their course; for, as was demonstrated by a simple diagram, collision becomes inevitable if the same bearing is maintained. So simple a mode of even lessening the probability of collisions, if not already generally adopted by nautical men, should be well noted.

At the same meeting a paper "On the Purification of Water," was presented by Mr. Dahlke. This related to a method of filtration devised by the writer, by which organic and most mineral impurities, including the salts of lead, were removed from drinking water; brackishness, also, by a judicious arrangement of this filtering medium, he stated might be removed to a considerable extent. He exhibited a filter that he had constructed which was partly tested in your presence; the further testing of its properties you will remember was referred to Mr. Newbery, who reported at the next meeting that the filter not only did all that Mr. Dalhke had stated, but he found it to possess powers of filtration beyond anything he had previously known; he had tried it very severely by filtering solutions of salt, sulphate of magnesia, and even sulphate of ammonium with it, and in every case the filtrate passed out as drinkable water, with barely traces of the substance previously in solution. Passing hot water in a reverse way through the filter removed the suspended salts and restored the activity of the filtering medium, which, after continued use, was diminished.

Some experiments were since tried on the filtration of sea-water by Mr. Dahlke, and I believe he is now engaged in the construction of a large filter for rendering brackish water fit for sheep and cattle at some station on the Darling river. There is no doubt that the kind of filter exhibited is exceedingly succesful as an ordinary domestic filter, but whether it will become practically successful in so remarkable a use as that of removing salt from sea or very brackish waters is not yet demonstrated.

I congratulate you upon these results of your past session, and I regard them as an evidence of increasing activity and an earnest of advancement in the objects of this society.

You will be glad to learn that our intercourse with kindred societies has increased; there are now 86 learned bodies with which we are in communication and interchange of publications; 41 of these are British, 36 continental European, 5 American, 2 Asiatic, and 5 colonial. Our library has been considerably increased by donations from these societies, and a complete catalogue, compiled by your honorary librarian, Dr. Neild, is appended to the second part of the last volume of our transactions.

I would now revert to the year's history and present state of our public scientific departments, and in doing so, if I speak at more length of matters concerning our observatory than of the other institutions, it is only because I am better acquainted with the details of its progress.

In my last address I told you that the Great Southern Telescope, which, by-the-by, is now to be styled the *Great Melbourne Telescope*, was approaching completion, and its arrival might be expected in the course of a few months. It has, however, not yet reached us. Several unlooked for delays in its construction occurred, principally owing to the determination on the part of the manufacturer, Mr. Grubb, that nothing but the very highest excellence in all its parts should go to its construction.

Many of you, no doubt, read the interesting letter of Dr. Robinson, of Armagh, which appeared in the daily papers a week or two since, respecting his inspection and trial of this great instrument, and that he passes a high eulogium on the excellence of its mechanical details, as well as of its optical powers, so far as he was enabled to judge from the imperfect trial he had with it in this respect. We are expecting every mail to hear of its shipment, and there appears to be every probability of its being even now on its way. M. Le Sueur, a gentleman selected by the committee as an observer for this telescope, comes out with it, and will occupy the position of second assistant astronomer at the observatory. Of this gentleman's high qualifications for the work before him we have the best testimony. You are aware, no doubt, that apparatus for celestial photography and spectrum analysis of the light of the heavenly bodies will form part of the appliances of this gigantic instrument, and I trust that Dr. Robinson's hope "that an inestimable harvest of discovery and triumph will crown this magnificent enterprise" will be fully realized. I have obtained a few photographs of a lithograph of the Great Melbourne Telescope, which will be handed to you at the conclusion of this address.

It appears that some kind of a building with movable roof will be necessary to protect it from the great damage likely to arise if exposed to the dust-storms we are liable to; it is therefore proposed to erect a circular building, with a revolving roof, and Parliament will be asked for a vote for this purpose. A small extension of the observatory ground has been granted, thus enabling the telescope to be erected in a position where it will command a full view of the heavens without creating any disturbance on our magnetic instruments by its too close proximity.

You will remember that in my last address I mentioned that a complete set of self-registering magnetic instruments or magnetographs (similar to those used at Kew) were expected to arrive shortly. These duly arrived; they have been erected and at work since November last, producing an uninterrupted photographic record of all changes of the forces of terrestrial magnetism.

A wet and dry bulb thermometer and barometer, continuously self-registering, on the same principle, are now being constructed for us, and will probably be at work in the course of a few months. The results likely to be obtained from the adoption of self-registering instruments of this kind can scarcely be too highly estimated, for the periodic method of observing phenomena that are changing continuously could never satisfactorily admit of those close deductions being made requisite to derive any practical value from the observations. Variations of the forces measured sufficient to establish or overthrow a supposed law may, and doubtless do, often happen in the intervals between intermittent observation, which, by the photographic or other self-registering method, is indelibly recorded with true relations to preceding and following variations.

The Melbourne portion of the survey of the southern heavens has made considerable progress; the portion of the heavens lying between the 150° 40′ and 152° 40′ parallels of declination have been thoroughly surveyed, and the positions of 19,000 stars established.

A series of observations for the determination of the difference of longitude between Melbourne and Adelaide, by aid of the electric telegraph, was made at the latter part of last year, and although the result is considered not quite conclusive, as it is intended to make another series of comparisons, it may however be accepted

as nearly the truth, and makes the difference of longitude 25m. 33.78s. Assuming the longitude of Melbourne to be correct, that of Adelaide would be 9h. 14m. 21.02s.

Before leaving the subject of our astronomical labors I would add a word concerning the total eclipse of the sun, which will take place on the 17th of August, this year.

The eclipse will be a most remarkable one, and unrivalled by any recorded in the annals of mankind in its magnitude and duration. At its commencement the moon will be unusually near the earth, and at the same time reaches the ascending node of her orbit. The sun also reaches nearly the zenith of those places where the eclipse takes place at noon; the augmentation of the moon's apparent diameter, due to her altitude, is a maximum; a combination of circumstances resulting in the apparent diameter of the moon exceeding that of the sun by an unusual amount, and in the time during which the sun will remain eclipsed, being almost unprecedented.

The greatest length of totality will occur in longitude 102° 38′ E. and 10° 28′ N. in the Gulf of Siam, where it lasts 6m. 50s. The path of totality, which commences at sunrise in Abyssinia, passes over the Straits of Babel Mandeb, Aden, Arabia, through India between Goa and Rajapoor, across the Gulf of Siam, where the greatest phase occurs, then through Borneo, the whole of the south of New Guinea, ending at sunset about the New Hebrides.

So unusual an eclipse as this is sufficient to put astronomers on the *qui vive*, for such an one has probably never been seen by man, and none of such magnitude is likely ever to be witnessed by any now living. But there are, however, higher objects than this in view, and great preparations are being made to carry out investigations concerning the sun's atmosphere, which can only be attempted during total eclipses, and for which this one offers so long a period of totality. It has long been supposed that an atmosphere surrounds the sun's exterior to the photosphere. Those remarkable red clouds or prominences and the corona or glory with its projections, generally seen in total eclipses, and especially in that of 1860, all point to this. These luminous clouds were found by Mr. De la Rue to have great photographic power, and Mr. Brayley concludes therefrom that they probably consist of incandescent globules of metal in a liquid state, or perhaps of solid particles of the metals discovered in the sun by Kirchoff. The optical means of analyzing the light from various sources have been so much improved since the last total eclipse witnessed by astronomers in 1860, and our increased knowledge of the physical conditions of the sun, as well as of many other of the heavenly bodies, induces the scientific world to confidently hope that the telescope, spectroscope, and heliograph will reap rich harvests in the hands of the many experienced observers who will be engaged in the path of totality.

The botanical department, so efficiently conducted by your fellow-member, Dr. F. Mueller, has not been idle. The "Fragmenta Phytographa Australis," I am informed, will have reached the completion of the sixth volume next month. Dr. Bentham's new work on the Australian flora (to which Dr. Mueller contributes largely) is progressing rapidly; the fourth volume containing the Candollian division—corolliflora—is nearly complete; the fifth volume, which it is expected will be issued next year, will contain the monochlamydeæ; and it is intended to follow it up by a sixth volume, containing the monocotyledons and ferns. A supplementary volume will afterwards be probably issued, to comprise the newer discoveries among cotyledonous plants, for which the "Fragmenta" will afford the principal records. This book will be the most complete descriptive work on the vegetation of Australia, and with which, in its completeness, no similar work on European vegetation can compare. You will be glad to learn that the cinchona (Peruvian bark) plants are prospering. Dr. Mueller informs me they have been exposed to extremes of temperature varying from 30° Fahr. last winter, to 100° Fahr. during this summer, in an artificial fern gulley in the gardens without injury;

this gives ample testimony of their hardihood, and their fitness for coping with the much smaller vicissitudes they would be liable to in the sheltered gullies of our mountain ranges. The establishment of this most valuable plant is of the utmost importance, and in a commercial point of view can scarcely be overestimated. There are now in the garden nurseries a large number of plants of cork oaks, western Australian mahogany, tea, tobacco, coffee, and other prominently useful plants, ready for planting in the valleys of the Upper Yarra this autumn.

Dr. Mueller made a botanical visit to western Australia during last year, and he informs me his principal object was to connect the observations of the flora of that colony with geological formations in continuation of the many facts he had traced out in other parts of Australia. An investigation of the mutual relations existing between vegetation and geological formations is of great importance as bearing on the general question of the occupation of the soil for various purposes of culture.

The phyto-chemical laboratory, under Dr. Mueller's direction, is still engaged in researches into the technological, medicinal, and other properties of the Australian vegetation, and especially as regards the amount of potash in our trees, which he states has already afforded highly satisfactory results. The question of the yield of iodine and bromine in our large sea-weeds is also occupying the attention of this branch of the botanical department.

Our national museum, under the management of Professor McCoy, continues to increase in its usefulness. It was highly praised by the naturalists and officers of the Italian scientific expedition, who visited us in the Magenta and who were fresh from the study of the best zoological collections in Europe. Our member, Mr. Ulrich, too, who has just returned from an inspection of the principal mining schools of Europe, finds them exceeded by the mining section of our museum, prepared by Professor McCoy with the object of facilitating the establishment of a school of mines in the colony by taking advantage of the proximity of the national museum to the university, in which eight out of the ten courses of lectures required are already given. The natural history specimens, mounted eight or ten years ago, still maintain their freshness and state of preservation, which is, no doubt, in a great measure attributable to the fact that the museum is surrounded by the well-planted university grounds, where it is free from the destructive influence of dust and smoke. Various classes of the university students make daily use of the different sections of the museum, while the number of the general public who visited this institution during the year amounted to 68,000.

Among the most interesting colonial specimens added during the year is the great skeleton of a new species of whalebone whale (*Physalus Grayi*, McCoy,) which is now beautifully articulated and placed outside the west wall of the museum. This specimen is 90 feet long. Next to this in interest are the further donations of Mr. Carson, of Enaliosaurian fossil reptiles from the Flinders, to be described in our proceedings as bearing out the views already laid before this society concerning the occurrence of these fossils in Australia. A very large iron meteorite, from Cranbourne, weighing 3,000 pounds, has been placed in the museum, which Professor McCoy promises to describe to us at an early meeting. Considerable additions, illustrative of foreign natural history, have been made, and the conchological collection, which is of great extent, is now almost completely named.

The geological collection is also largely increased, as well as that of the different *Articulata;* but it appears that there is no more room at present in the half of the museum already built for their display.

From the report of the government geologist, Mr. Selwyn, just published, we are put in possession of the progress made in the geological survey of the colony. It appears that 55 quarto sheets, each of which contains the geological features of 54 square miles, have already been published, and that 11 are ready for the engraver. A collection of 1,248 geological specimens has been arranged and

labelled for the national museum. Besides the strategraphical arrangement of these specimens, each is labelled with numbers and letters, indicating its locality and the map to which it belongs. Considerable additions to the geological sketch-map of the colony have also been made by the director from his reconnoissance surveys in various districts. The department, however, has been singularly crippled during the past year, owing to the absence of some of the officers on leave, and the sickness of others. The survey has, nevertheless, made considerable progress, especially in the districts of south Ballarat and north of Creswick and Clunes. It appears that a party has been engaged in the first-named locality on a research into the course and limits of "deep leads" of the Ballarat gold-field, which has already resulted in Mr. Murray, the gentleman engaged in this portion of the survey, being enabled to indicate the existence of payable gold deposits in a locality where, though frequently traversed by miners, no workings had been established.

In contemplating the more interesting facts that have marked the progress of science in Europe, our attention is attracted by a recent discovery of paramount significance.

In the spectra of many of the fixed stars the lines proper to hydrogen have been observed, and in the outburst of the light of the star T-Coronæ, some time ago, the development of these lines was so conspicuous as to lead to the inference that an outburst of hydrogen, of the nature of a general volcanic eruption, had taken place in this star. Singularly in agreement with these observations are certain results determined by Dr. Graham during his researches on the occlusion of gases by metals.

This exact chemist has shown that the different metals have properties of their own of condensing the various gases, and concealing or occluding them within their substance. In the case of meteoric iron, he has found that it is not only charged with occluded gases, but that the gases thus enclosed are different in kind from those concealed in iron of telluric origin. Common iron bears the impress of the mode by which it has been manufactured in the large proportion of carbonic oxide and carbonic acid as constituents of the gases stored between its particles, whereas, on the other hand, the iron of the Lenarto meteorite has yielded abundance of hydrogen gas almost entirely free from gaseous carbon compounds.

On these results Dr. Graham remarks, "The iron of Lenarto has, no doubt, come from an atmosphere in which hydrogen greatly prevailed. The meteorite may be looked upon as holding imprisoned within it, and bearing to us, hydrogen from the stars." Speaking of the amount of gas given up by this meteoric iron being three times the amount found in iron of telluric origin, he further says, "The inference is that this meteorite has been extruded from a dense atmosphere of hydrogen gas, for which we must look beyond the light cometary matter floating about within the limits of the solar system."

A few years ago results of this kind would have been deemed almost beyond the hopes of even the most sanguine philosophers. Dr. Graham presents to us in a tangible form the hydrogen brought from remote regions of space to which possibly our most powerful telescopes have yet failed to reach. He demonstrates that it must have come from a dense atmosphere of the gas found; and, what is of still higher interest, his experiments conduce towards the view that the so-called chemical elements of our world are so framed as to adapt them to uses throughout the entire scheme of nature.

In conclusion, I will for a moment return to the affairs of the society. There seems to be every prospect of steady progress. I am rejoiced to see the members earnestly following up the objects for which this institution was intended. Our efforts, whether they have for their aim the investigation of the laws of nature, the development of our natural resources, or the alleviation of the sufferings of our fellow-creatures, although, perhaps, crowned with only partial success, have

each the effect of promoting our advancement as a people, and of raising the estimate of the intellectual status of this colony in the minds of the intelligent in other parts of the world. In these days no apology for scientific experiment is required, for although the primary object of science is the discovery of truth, it is now universally admitted that the contributions applied to the arts of life are among the most valued means by which our civilization is advanced. In a new country the problem of the utilization of its resources opens the widest opportunities for the adaptations of science to practical requirements. An example will illustrate this general assertion: let us for a moment consider our relation with the older countries in reference to the supply and demand of the one important item of animal food. We have inexhaustible means of supply, while in European countries flesh food is becoming yearly scarcer. Any improved method of animal food preservation, assisting its transport, would be a vast accession to our means of wealth, and to this end the facts of chemistry in relation to physiology appear as affording the proper key. The case of food supply is by no means a solitary instance; the same reasoning applies generally to the natural resources of a new and extensive country like Australia.

In these and like considerations let us hope that a sufficient stimulus for our best efforts will be recognized, and that our endeavors will be so far fruitful as to entitle the Royal Society of Victoria to rank in due time with similar older institutions in Europe and America.

REPORT ON THE TRANSACTIONS OF THE SOCIETY OF PHYSICS AND NATURAL HISTORY OF GENEVA, FROM JUNE, 1867, TO JUNE, 1868.

BY PROFESSOR ÉLIE WARTMANN, PRESIDENT.

[*Translated for the Smithsonian Institution.*]

The report which I have the honor of submitting to my colleagues of the Society is the eleventh of those which have been presented under our existing regulation. Like my predecessors, I propose to recall the different communications which have been made, by grouping them according to their subjects. Like them, too, I would renew the recollection of the amicable discussions, the free and unconstrained developments elicited by the reading of a memoir, or even the simple statement of a question. It is the privilege of our association to have no official connections, to observe only our own traditional customs, and to permit its members to exchange ideas with a mutual kindliness, which certainly does not exclude a sincere love of truth. This form has so many charms and advantages that I trust it will long be preserved. When in 1890 the society shall celebrate the centennial anniversary of its foundation, it will be able to point with pride to the fact that it has served in no stinted measure to unite and encourage those of our compatriots who devote themselves to the culture of the natural sciences.

Thanks to the care taken by our secretary, M. Alex. Prevost, in recording our proceedings, I may hope that my account of them will, at least, have the merit of exactness. The society has held during its current year twelve general and eight special sessions. No modification has been introduced in its rules. The old custom of assembling for tea previous to our winter sessions has, after discussion, been retained.

Dr. Lombard has been called to exercise the functions of president during our approaching term, 1868–'69. M. Marc Micheli has been elected a member in ordinary, as has also M. Godefroy Lunel, who already belonged to us as a free associate. It is with sincere pleasure that I record this increase in the number of our members, which now amounts to 42. No death has occurred among them within the year. Unfortunately, it is not so with our honorary members, three of whom have been taken from us.

Dr. Michael Faraday, one of the most distinguished savants of England, and our associate for a quarter of a century, departed this life 25th August last. The labors of this eminent physicist are too well known to require enumeration here. No time was lost by M. de la Rive in rendering a touching and worthy homage to the successor of Humphry Davy.* I had myself, for several years, cultivated the most pleasant relations with this kind-hearted man, in whom a genius full of originality was allied with the most unaffected modesty. To science, as to his personal friends, the loss is irreparable.

Six months later, Leon Foucault, an intellect of a high order, was withdrawn from us, at the age of 49 years, a victim to immoderate application. He was

* *Archives des sciences, physiques, et naturelles*, t. xxx, p. 131. This notice has been reproduced in the journal *L'Institut*, and in the *Philosophical Magazine*. [also in the Smithsonian Report for 1867, p. 227.]

endowed with no common faculties, and resembled Faraday in the incompleteness of his earlier studies, which both had afterwards found the means of retrieving through special methods, in conjunction with great decision of purpose. Looking upon evidence as the only unimpeachable demonstration of truth, Foucault had conceived and executed the most delicate researches. His mechanical dexterity was incomparable, and, had he lived longer, would have been made available for the solution of many other problems. He was a warm friend, an ingenious and penetrating spirit, a clear and accurate writer. He leaves in the history of physics profound traces which will preserve his name from oblivion. He was received into our society in 1859.

Dr. Charles Daubeney, recently deceased in England at the age of 73 years, has been a colleague of ours since 1830. He had pursued at Geneva, under Pyrame de Candolle, his studies in botany, a science of which he was subsequently a professor in the University of Oxford. We are indebted to him for a great number of researches in different departments of the natural sciences. In our city he had made many friends, to whom he has always remained greatly attached.

After this tribute paid to the memory of savants who are no more, we may congratulate ourselves on having inscribed upon our list the name of M. Claude Bernard, the distinguished French physiologist. None among us but remembers the interesting communication on the curare, and on poisons in general, which he presented, in 1865, to the Helvetic Society of Natural Sciences, assembled within our walls.

§ 1.—ASTRONOMY.

Has the moon, our nearest neighbor in the immensity of the heavens, arrived at a definitive state, or can we still discover some changes on its surface? This question, so important for cosmology, has been almost universally answered in the negative. Professor Gautier recounted to us (4th July) the researches made at Athens, by Dr. Schmidt, on the transformations undergone by the crater Linnæus, in the *Mare Serenitatis*. Affirmed by different observers, for instance by M. Respighi, at Bologna, these modifications have been called in doubt by other savants. Thus M. William Huggins maintains that the appearance of the Linnæus is exactly that which Schröter has figured in plate IX of his *Selenotopographische Fragmente*. This divergency of views gives interest to the observations reported to us by M. Thury, (1st August,) and which he made by means of an excellent refractor, mounted at the atelier of Plainpalais, with an objective, furnished by Mertz, of four and a half inches opening. Our colleague thinks that the crater has become filled with a substance of a whiteness like that of ceruse, so that its configuration differs from that represented by Mädler in his celebrated chart. (See *Archives des Sciences, Physiques, et Naturelles*, t. xxx, p. 292.)

M. Gautier has continued, as in former years, to communicate to us the uninterrupted progress of the noble science to which he has devoted himself. He announced the arrival at Labrador of two thermometers, which he had sent to the Moravian missionaries through the medium of our countryman, M. J. L. Micheli. These instruments will be used for a regular study of the temperature of those glacial regions. He gave us an account of the researches of Dr. W. Schur on the orbit of the double star *p*, in Ophiuchus, from which we are authorized to estimate at about 94 years the period of the revolution of the smaller star around the larger. By adopting the value of the annual parallax of this group obtained at Bonn, by Dr. Krüger, the mutual distance of the two stars would appear to be about 30 times the distance from the earth to the sun, the mass of the group to be triple that of the sun, and its light to occupy 20 years in reaching us. He brought to our notice the observations of Dr. Auwers,

at Gotha, on the parallax of the star of eighth to ninth magnitude, No. 34 of the catalogue of Groombridge, the distance of which from the earth is computed to be but 672,000 radii of our orbit. M. Gautier also directed our attention to the improvements effected in different instruments of astronomy and meteorology, and adverted to several new asteroids situated between Mars and Jupiter. The discovery of these planets commenced with the present century, and their number reaches to-day nearly 100.

Professor Plantamour gave an account (21st November) of the mechanical processes by help of which he takes observations, registered by a chronograph. The scene of his labors this year was the Righi. These observations have reference to the determination of gravitation, and to other questions submitted to study by the International Conference for the measurement of the meridian between two parallels comprising an arc of 22° in middle Europe.

Since the admirable discoveries of Kirchoff and Bunsen relative to the spectral analysis, the learned have investigated with much ardor the problems bearing upon the physical constitution of the sun. One of our colleagues, Colonel E. Gautier, has directed his attention specially to the theory of the spots, and exhibited to us (4th July) an eye-glass manufactured at Munich, which is intended to enfeeble, by polarization, the too vivid lustre of the luminary. It would seem to result from observations conducted with this instrument that the solar spots have a very different appearance from that attributed to them. The importance of enabling astronomers to examine these phenomena gave occasion, almost at the same time, to the invention, by the ingenious Leon Foucault, of a silver-plated reflecting telescope. We may hope, therefore, that with the aid of these new instrumentalities science will soon arrive at certain conclusions on this difficult subject. M. E. Gautier has further given, in our meeting of this day, (4th June,) the analysis of a memoir published by M. Spœrer, professor at Anclam, on the spots of the sun, in which the author treats of the law of their velocities of rotation according to their heliographic latitudes, and of the irregularities which disturb that law. In effect, neighboring spots seem sometimes to undergo a sort of torsion, with other anomalous appearances. These anomalies result from the modifications, often very rapid, which are observed in the aspect of the spots, when a magnifying power sufficiently strong is employed, and atmospheric circumstances are favorable. We may then recognize variations, resolutions, and new formations comparable to those of our terrestrial clouds. M. Spœrer draws from this a confirmation of the idea, already announced by him, that the spots are situated above the brilliant surfaces on which the faculæ are developed. Notwithstanding the accidental changes of velocity whose phases have been studied, the author refuses to believe that the general movement of the solar surface around its axis varies by zones, or by rings parallel to the equator. M. Spœrer examines, moreover, the proportional distribution of the spots and faculæ on the different portions of the orb, as well as the relations of this distribution to the phases of the period of 11 years which has been recognized in the frequency of these phenomena. He afterwards attacks the Wilsonian theory regarding the funnel-shaped spots. He exerts himself to weaken the bearing of the calculations of English astronomers on the mean-proportionals which they have deduced from photographic observations of the sun in relation to that theory. He refutes the attempts of M. Faye tending to introduce a correction termed parallax of depth, in order to make the calculation of the places of the spots quadrate with the observations derived from the work of M. Carrington. He maintains the views of M. Kirchoff on the constitution of the sun, and concludes with some ideas touching the manner in which the spots may be formed. They might be generated by intense ascending currents of gaseous matter which burst forth from the sphere in fusion and become condensed in the solar atmosphere at different heights. These formations would remain or fall back according to the

velocity communicated to them by the strata into which they penetrate, and wherein they diffuse themselves.

§ 2.—METEOROLOGY.

Professor A. Gautier read (4th July) an extended notice of the results obtained from December, 1865, to November, 1866, during the third year of observations made at the 76 stations of Switzerland, under the two-fold view of temperatures and quantities of rain. This production has been inserted in volume xxix of the *Archives des Sciences, Physiques, et Naturelles.* I will content myself, therefore, with citing a conclusion but little known; namely, that the mean temperature of Geneva is higher than that of the other cities of our country, with the exception of Bellinzona, Lugano, Mendrisio, Montreux, and Sion. At the close of the last-mentioned communication, Professor A. de Candolle expressed a regret that the methods by means of which meteorologists establish the mean of the numbers they collect, render the results of their calculations nearly useless to botanists. He remarked that the phenomena of vegetation continue for some months, during which it would be important to know the sums of the temperatures above a certain degree previously fixed upon.

§ 3.—MATHEMATICS AND PHYSICS.

The sun, that source of complex radiations which call forth the most diverse and important phenomena, dispenses to us heat varying as to quantity with the seasons, and as to composition with the state of the atmosphere. By means of the actinometer which he presented last year to the society, M. L. Soret compared (5th September) the intensity of the calorific radiation at Geneva with its value on the glacier of the Bossons and at the summit of Mont Blanc; he found that when the sun is 60° above the horizon, the radiation at a height of 4810 meters is to that on the plain in the ratio of six to five. The diminution of intensity with the height of the sun is much less considerable at a great altitude than in regions less elevated. To these observations, made in August, M. Soret has added others during the winter, whence it results that, for the same height of the sun, the intensity of the direct radiation is then greater than in summer, which accords with the part which, according to M. Tyndall, is borne by the atmospheric vapor in the phenomena of absorption. Our colleague has ascertained that, at an equal elevation of the sun, the radiation diminishes more rapidly when the heat has traversed a watery stratum than when the rays are direct. The recital of these results was the occasion of interesting discussions, calculated to guide the author in new experiments.

The question whether the sea is free at the pole was raised in connection with these estimates of the thermic intensity of the solar radiation. M. Soret also took occasion to state (19th December) that ozone, prepared by the action of the apparatus of Ruhmkorff on oxygen, possesses the same density with that obtained by electrolyzing water. (*Archives des Sciences, &c.*, t. xxx, p. 306.)

Professor de la Rive presented (6th February) the analysis of researches by M. Elias Loomis, leading to conclusions very favorable to the electric theory of polar auroras, proposed by our colleague. (*Archives des Sciences*, &c., t. xxxi, p. 273.)

Among the phenomena whose study promises to enlarge the field of our knowledge of the intimate constitution of bodies, none are more interesting than those of rotary polarization. Detected in quartz by Arago, in 1811, this mysterious property has been found in solids of regular system, in homogeneous colorless liquids, and in certain vapors, though no permanent gas, even when compressed, has heretofore manifested it. It is therefore independent of the crystalline state, and, according to the substance employed, takes place some-

times to the right, sometimes to the left of the observer. Further, it may vary in direction in the same body with the tint of the light which traverses it, for we have notice of a liquid which is lævogyral for the rays of one extremity of the spectrum and dextrogyral for those of the other extremity. When Faraday found, in 1845, that the plane of polarization of a ray traversing an inactive substance may be made to turn by placing the substance within the magnetic field, he enhanced in an unexpected manner both the interest and the difficulty of this problem of molecular mechanics. Wiedemann showed that this artificial rotation increases in proportion as the length of wave of the colored ray diminishes. Verdet ascertained that there exist substances for which the rotation is positive, others for which it is negative, (that of water being taken for unity,) but that it is not necessarily connected with refrangibility. Wertheim deduced from his experiments that in general it is absent in solids endued with double refraction.

Is rotary polarization owing to an action exerted by the substance which transmits the luminous (or calorific) ray, or should it be referred to an influence experienced by the ether which surrounds and penetrates matter, properly so called? The first of these suppositions was taken into favor when Faraday found that the magnetic rotation is distinguished from the natural, by the very important fact that it augments with the length of the course of the ray, whether direct or reflected, in the transparent medium.

Professor de la Rive has resumed the study of this subject, and communicated to us (7th May) a comprehensive review of his experiments. These have been made with divers solids, among others glass compressed by the fulminating discharge of Ruhmkorff's machine, as well as with different liquids. Our distinguished colleague had already remarked, (*Traité d'Electricité*, t. i, p. 555,) that the phenomenon seems connected in an essential manner with the density more or less considerable of the intermolecular ether, and consequently with the refractive power of bodies; but in his new researches he has found that the density of the body itself exercises a great influence, independently of that of the ether which it includes. Thus, with the electro-magnetic intensity at his disposal, he has ascertained that the rotation being 8° in sulphur of carbon having a density of 1,263, it became 16°, that is precisely double in thallic alcohol, a liquid of which the refrangibility is slightly superior, and which possesses a density much more considerable, (3.55.)

It is known that the rotation of the plane of polarization persists for some instants after the electric current has been interrupted. M. de la Rive has satisfied himself by a great number of experiments in which he has succeeded in measuring the duration of that persistence, and in appreciating the circumstances which influence it, that this effect cannot be explained by the inertia of the ponderable molecules. It is a consequence of the magnetism remaining in the iron of the electro-magnet, for it no longer takes place when inductive spirals simply, without a metallic nucleus, are employed. M. de la Rive concludes that artificial rotary polarization, although greatly influenced by the molecular constitution of bodies, is not due to an alteration which magnetism might determine in that constitution, but rather to an action exerted indirectly on the ether through the medium of the ponderable particles. This explains why the phenomenon depends at once on the state of the intermolecular ether, and on the arrangement of the number and the nature of the particles in a given volume of a body.

M. Achard recapitulated (April 16) the conclusions of a popular lecture given by M. Clausius on the second principle of the mechanical theory of heat. According to the last-named savant, the work which natural forces can execute, and which is contained in the movements of the different bodies of the universe, is successively tranformed into heat. This heat seeks incessantly to pass from warmer bodies into colder ones, so that there will be gradually established a definitive equilibrium between the heat radiating into ether and that which

exists in bodies. To express this progressive change M. Clausius imagines a magnitude which, in relation to the transformations, would play the same part as heat in relation to energy and work, and he calls this magnitude *entropie*. The result of his philosophic views he expresses by saying that the entropy of the universe tends towards a maximum. Thus the modifications undergone by the creation, instead of having a periodical and circular course, always take place in a definite direction and tend towards a limitary state. If that state be some day attained, no ulterior change will be possible, and the universe will lapse into a condition of persistent death!

M. Charles Cellerier presented (May 7) two notes; one relating to the theory of prime numbers, of which a mean law may be found more approximate than that indicated by Legendre; the other devoted to the calculation of the attractions and repulsions in electrified bodies. M. Cellerier demonstrates that, whatever be the form and arrangement of several insulated conductors, the total potential possesses for each of them, at every instant, a constant value in its whole interior. Moreover, if we compute the sum of the products of the potential of each conductor by the total mass of the electricity which covers it, the variable quantity thus obtained has the property of representing double the labor of the forces exerted on the material conductors themselves, when these are displaced in any manner. The calculation for the special case of two spheres serves for confirmation to this general theorem.

Some communications were also made by your president. He exhibited a sample of the infusion of Cuba wood, or braziline, discovered by Professor Geppelsröder, which is endowed with a very decided fluorescence. He submitted to your notice the new magnifying glasses of Adolphe Steinheil, formed by the conjunction of three lenses, and possessing the double advantage of being achromatic and of not destroying the images on the contour of the visual field. He described the electro-magnetic pendulum of Tiede, which has served Professor Förster, director of the Astronomical Observatory of Berlin, to determine the correction which should be applied to the speed of a clock for the variations of the atmospheric pressure. He presented the new electric machine of Holtz, and repeated the unpublished experiments of M. König on the determination of the upper limit of sounds perceptible from the concussion of bars of steel calculated by length. He called attention to a singular case of permanence in a charge of electricity induced in a long wire, a case observed in England by M. Wild. He pointed out an elementary solution of the problem of the trisection of the angle. Finally, he described experiments which he had made with the improved regulator of Léon Foucault for the electric light. These researches confirm the results which he communicated to the society in 1852, namely, that with a battery which works well and a delicate apparatus, the current may be interrupted during one-thirtieth of a second without inducing variation in the illumination of a screen exposed to the light of the arc. The armature of the electro-magnet is not uncharged, and no sound of any action is heard. If the interruption is longer continued, both the eye and the ear are apprised of it. When the interruption attains one-tenth of a second the arc vanishes. I conclude from this, and from considerations which would detain us too long if detailed here, that when the interruption is sufficiently short, the arc continues to exist, contrary to the opinion of M. F. P. Leroux, who recognizes a cessation followed by the spontaneous re-establishment of the arc. (*Comptes Rendus de l'Académie des Sciences de Paris*, t. lxvi, p. 155.)

§ 4.—CHEMISTRY.

M. Delafontaine has ascertained (21st November) that the molybdates dissolved in fluorhydric acid give rise to a new class of salts, the fluoxymolybdates, which present the most complete analogy with the fluoxytungstates and the fluoxynio-

biates discovered by Professor Marignac. An attentive study of the crystalline forms has established their isomorphism both with these two categories of saline products and with the bodies, such as the fluotitanates, in which the fluor is completely substituted for the oxygen. The author has confirmed the fact established by M. Marignac that the fluor replaces atom for atom the oxygen as the isomorphous element. *(Archives des Sciences, &c., t. xxx, p. 232.)* M. Paul de Gasparin (invited to one of our reunions) recounted to us (7th May) the principles of the physical analysis of arable lands in the view of determining the relative proportions of gravel, sand, and clay which exist in the cultivated soil. But this analysis does not necessarily manifest the degree of fertility of a given soil, for it cannot evince the very variable proportions of phosphoric acid, potassium, magnesia, and other mineral substances which fulfil the functions of manures.

§ 5.—MINERALOGY AND GEOLOGY.

M. de Loriol (2d January) having, in company with M. Cotteau, studied the Portlandian stratum of the department of the Yonne, has found it to be divided into two zones: the lower one with but 13 fossil species and characterized by the *Ammonites gigas*, the upper with 110 species and characterized by the *Pinna superjurensis.* The lower zone presents the remarkable fact of the intercalation, in the midst of the limestone, of a thin marly bed filled with the *Ostrea virgula.* The first strata of the middle neocomian rest immediately on the last Portlandian strata. The zoological limit, however, is sharply defined; no species is common to the two faunas. Professor Favre (7th November) presented us his work in three volumes, entitled: *Recherches géologiques dans les parties de la Savoie, du Piémont et de la Suisse, voisines du Mont-Blanc,* (Geological researches in the parts of Savoy, Piedmont and Switzerland, adjacent to Mont-Blanc,) with an atlas of 32 plates. Proceeding in the traces of Horace de Saussure, Deluc, Necker and other explorers, our colleague has brought a large contingent of personal observations towards deciphering the enigma of the formation of the Central Alps. The medal awarded to his geological chart of these countries by the jury of the Exposition of 1867, enables us to presage the reception which the text that completes it will receive. The society may well congratulate itself at seeing members like MM. de la Rive, Pictet, Boissier, de Candolle, Favre, de Saussure and others, employed in collecting in special works and in a systematic form, not only their own numerous researches, but those which other savants have dispersed in memoirs and monographs. There cannot but ensue from this a more precise statement of general results, a more exact view of laws and their relative importance, a more certain classification, and a more profound examination of obscure or doubtful points. Science is advanced by being embodied in a systematic form. *(Archives des Sciences, &c., t. xxxi, p. 123.)* M. Favre has, at different intervals, placed under our eyes wrought silex and fossil bones collected for some time past at different places on Mt. Saléve. The first discoveries go back to at least 1835; I possess some pieces which I then met with in the caverns of Veyrier while making botanical and geological excursions. The specimens collected by our colleague are implements of flint mingled with the relics of the reindeer, and ascend to the most ancient period of the age of stone. He has seen a bone ornamented with a design which represents an animal, (probably a wild goat,) and another bone on which a plant was carved. M. Favre computes that the station of Veyrier is posterior to the glacial period, and that the reindeer then abounded in our neighborhood as it now abounds in Norway. It was probably in the facilite of Mornex, on the lesser Saléve, that the material was sought, at that remote age, for executing the carved implements of Veyrier and the environs. Nothing, however, authorizes us to infer the existence of the human race anterior to the glacial epoch. *(Archives des Sciences, &c., t. xxxi, p. 246.)* M.

Favre announced (5th March) that the Society of Natural History of Berne had purchased, in order to insure its preservation, an erratic block measuring 320,000 cubic feet and situated near Interlaken. It is a beautiful red granite of unknown origin.

§ 6.—BOTANY.

The natural sciences have assumed a new phase since the publication of Darwin's work on species. What is designated by that word? And, since species is variable, how is that variability to be indicated? By what artifice of nomenclature are we to reveal to the savants of future times the metamorphoses and filiations which are accomplished under our eyes?

These philosophical problems have rendered the naturalists of different countries sensible of the utility of reunions in which they may be discussed in a scientific manner. Our society has not been insensible to the honor conferred on one of its members, who was called in May, 1866, to preside over the first congress of botanists assembled in the capital of England. The committee of the botanical society of France, charged with organizing a second session at Paris, in August, 1867, invited M. Alphonse de Candolle anew to act as president of that assembly. The learned professor had given us the programme of a plan relative to the laws of nomenclature, in which, for the first time, he had co-ordinated them as the articles of a code. This plan, submitted to a special commission, was adopted by the congress, which caused it to be inserted in its transactions. After an enunciation of general principles, the different subjects are grouped according to their nature, and each provision is marked with a number, so that it can be always referred to with distinctness. It is known that Linnæus has given laws under phrases thus numbered, but he has not indicated the directing principles; many of his laws were arbitrary and certain points of view completely pretermitted. M. de Candolle has been more methodical and more complete than his predecessors. He has been led to justify the usages followed by his father, by Adrien de Jussieu, Robert Brown, Hooker, Lindley, and still observed by MM. de Martius, Bentham, the younger Hooker, and others. By an immense majority of the members of the congress, the system of our colleague was voted to be *the best guide to follow for botanical nomenclature.* *

At another session (7th May) M. de Candolle presented to us some additional details on the subdivision of cultivated species into *hybrids*, mongrels, (*métis*,) *semis*, and *lusus*. The hybrids being designated by the sign X, the métis by x, the author proposes the sign $\surd$ to distinguish the semis and a z for the lusus. Such, it may be added, is the stage of advancement of descriptive botany that, at the end of the present century, nearly the whole of the genera will probably be known, while much will remain to be done in the investigation of species. (*Archives des Sciences, &c.*, t. xxx, p. 278.)

M. de Candolle called our attention (2d January) to a note of M. Venance Payod, of Chamonix, on vegetation in the region of ice; it comprises a very complete list of vegetable species which are grown at the garden on the slopes of the Mer de Glace and its affluents. The same member gave an account (5th March) of his researches respecting the important family of the Cycadeæ.

It is at present composed of nine genera and 64 species, half of which inhabit America, while the rest are divided between the Old World and Australia. It is scarcely probable that the whole actual number of species exceeds 100, while it made a conspicuous figure in ancient geological times. A thorough examination of facts leads M. de Candolle to adopt the opinion of Robert Brown on the nature

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* *Lois de la nomenclature botanique*, adopted by the international congress of botany, held in Paris in August, 1867; followed by a second edition of the *Historical Introduction and Commentary* which accompanied the preparatory summary presented to the congress. Geneva & Bâle, Georg, editor: a volume of 64 pages.

of the fruit of the cycadeæ and of the coniferæ. This fruit proceeds from a naked ovule, without ovarium, inserted on an organ analogous to the leaves. To all the arguments which have been advanced with this view, he adds that in certain of the coniferæ, such as the *podocarpus*, the ovules are anatropous, a mode of development absolutely unknown among ovariums. He does not hesitate to affirm that the gymnosperms are dicotyledons, and have only external resemblances of vegetation or aspect to vascular cryptogams. M. de Candolle has further shown us (4th July) the acorns of an oak, a native of California, which present a groove near the edge of the cup, as if they had been compressed by a cord.

On occasion of the analysis made by M. Aloïs Humbert of a new work which Mr. Wallace is about to publish on the classification of varieties in the animal kingdom, (especially in the genus *Papilio*,) M. de Candolle remarked (16th April) that varieties have not been more studied in botany than in zoology. There are not as many which are local among vegetables as among animals; nevertheless there exists a certain description of forms according to the nativity. A facies, difficult to be defined, will sometimes indicate to a practiced eye the origin of different plants. We will cite, in the last place, the examination into which M. de Candolle entered (16th April) of the work of MM. Perrier and Saugeon on the distribution of species in the Alps of Savoy. It has been long remarked that certain alpine regions are distinguished by a very poor flora, while at other points it is very abundant, as at Mount Cenis, at the Saint Bernard, at Zermatt, and in the neighboring localities, up to the confines of the Valais and of Italy. MM. Perrier and Saugeon attribute this fact to an anthraciferous geological formation which bisects the Alps from Mount Cenis, and borders to the south the chain of Mont Blanc, comprising Cramont, Saint Bernard, &c. M. de Candolle contests the influence which the geological formation is capable of exerting on vegetation. Deposits indeed exercise an influence through their physical and mineralogical qualities, and that on every species of stratum. The anthraciferous formation is very ancient, and vegetation did not commence until after the glacial period. The great chain must then have been the center of an immense accumulation of snow, in the vicinity of which only arctic plants could subsist. In proportion as the glaciers diminished, the species of the plain ascended, especially on the southern flank. Hence the origin of the vegetable wealth of certain localities, which, therefore, is not to be imputed to the geological formation. Thus it is remarked that the plants to the south pertain to families relatively more recent in a paleontological point of view; such are the composites, the campanulaceæ, the primulaceæ, &c., which do not occur among arctic vegetables. Rev. Dr. Duby communicated to us (4th July) the first part of a memoir entitled "*Choix de Cryptogames exotiques ou mal connues*," (selection of exotic or little-known cryptogams.) He treats therein more particularly of 12 species of mosses, 10 of which are new, while two had been imperfectly described by Schwägrichen. Five of these species belong to Mexico, one to Uruguay, one to Colombia, one to Patagonia, one to Chili, one to the Cape, one is met with at the Cape and at the Antilles, and a last one at the Antilles and the Mauritius. They are distributed among the genera *Campylopus*, *Orthotricum*, *Macromitrium*, *Schlotheimia*, *Fabronia*, *Hookeria*, *Hypnum*, and a new genus allied to the *Macromitrium*, which M. Duby names *Monoschisma*. (See the present volume of the *Mémoires de la Société*.) The same member described (19th March) the new champignons of the family of the lycoperdaceæ, which Dr. Westwick has found in the kingdoms of Angola and Benguela. They are remarkable for their dimensions, some attaining a demi-meter in height. In these species the seed escape circularly by a series of small holes, while in the species of Europe they issue only by a single opening at the top. Dr. Gosse pointed out (5th December) the appearance of female flowers on some male plants of *Dioscorea batatas* cultivated in our canton. Dr. Müller recounted analogous cases of diœcious plants having become mon-

œcious. The same botanist reported, on the authority of MM. A. Famintrin and Baranetzky, interesting details on the culture of the isolated gonidia of the *Parmelia parietina*. These facts are a proof of the existence of zoospores among the lichens.

§ 7.—ZOOLOGY.

At the last meeting of the previous academic year, (6th June,) Prof. E. Claparède presented to the society the result of his comprehensive researches on the Annelides. This work will occupy two of the annual volumes of our memoirs, and will not be the least ornament of the series. Our learned colleague explained (4th July) the origin of certain valves observed at the extremity of the bristles which cover the feet in some of these species. At the time of their egress these bristles pierce the integuments by means of hooks covered with a hood, and this hood, which is caducous, remains sometimes in the shape of two valves at the extremity of the bristle. Our colleague has recognized in the case of a man who had died of a disease of the liver, that the reputed cyst formed in that organ, and which had attained the size of a man's head, resulted from an aggregation of *Echinococci*. It is only a phase of the development of the tœnia of the dog, the egg of which is transformed into the *Echinococcus* in the interior of the body of ruminants and of man. This explains the great abundance of this parasite among the people of Iceland, where the number of dogs equals one-third of that of the inhabitants.

M. Godefroy Lunel, keeper of the museum, exhibited to us (3d October) the admirably colored plates of a memoir on the fishes of the lake of Geneva, which will be published by the Zoological Association of the Leman. M. Lunel finds the number of species equal to that which Prof. Jurine has described in a memoir inserted in vol. iii of our repertory; but it is by separating the trout of the lake from that of the rivers, and by suppressing one of the species admitted by the last named naturalist. M. V. Fatio discovered (21st November) in the museum of Neuchâtel a specimen of an old female tétra bearing the external appearance of the male. In this connection he discussed some cases of cross-breeding between neighboring species, and affirmed that these crosses are less rare than is supposed.

M. H. de Saussure was designated to describe the hymenoptera collected during the voyage of the Austrian frigate Novara around the world, (1857–'59.) He has taken this occasion to publish the new species brought from the east by M. Aloïs Humbert. The same member rendered a just homage to the virtues and talents of the Vaudese naturalist, Alexander Yersin, removed by death in the flower of his age, after having made himself known by remarkable researches on the stridulation of insects. M. de Saussure has offered us the biographical notice consecrated to the memory of his friend.

In presenting to us the cast of a skeleton of the gorilla, of natural size, Prof. Pictet pointed out (1st August) the differences observable on a comparison with the human skeleton. There has been recently found a new species of chimpanzee, the stature of which nearly approaches that of the gorilla.

§ 8.—ANATOMY AND PHYSIOLOGY.

Dr. Claparède explained (21st November) the latest researches instituted by M. Dubois-Reymond on muscular electricity. The results at which the Berlin physiologist has arrived, by the employment of new instruments, are quite different from his older determinations. (*Archives des Sciences, &c.*, t. xxx, pp. 359, 364.) The same member presented (5th December) a series of designs relative to the anatomy and embryogeny of some species of acari. In the hydrachni, and especially the *Atax*, the formation of the embryo in the egg involves the

rupture of the shell; but the embryo, instead of being free, is enveloped in a membrane or *deutovum*, whence it afterwards issues, first as a larva with a carapace, to be transformed secondly into a larva without carapace, and finally to become a perfect animal. In the embryo, as in the adult, the circulation is supplied by the existence of alternating or amœabean corpuscles, which insinuate themselves among the organs, and are the equivalent of the corpuscles of the blood in other animals. M. Claparède has extended his researches to the parasitic acari of the skins of divers of the *Rodentia*. He has observed that these minute creatures have organs of attachment analogous but not homologous, a fact which is favorable to the theory of the gradual transformation of species in the sense of Darwin. A parasite of the *Mus musculus* presents an egg, a deutovum and tritovum, a circumstance hitherto unobserved. According to M. Aloïs Humbert, the analogue of the deutovum occurs in the myriapod *Chilognathus*. It has been seen also in the *Julus*, and been named the pupoid body. It exists likewise among the *Glomeris*, in which, like the egg, it is spherical.

M. Claparède has occupied himself also with another acarus, the *Tetranychus* of the Linden. It is known that in a great number of articulata, the blastoderm appears around the vitellus without previous segmentation. Now, in the *Tetranychus* the formation of the blastoderm takes place by the division, repeated many times, of a primitive cellule placed at the surface of the vitellus. The nucleus of the cellule is of doubtful origin; it is probable that it constitutes the germinative vesicle. This cellule should be considered as a vitellus of formation which constitutes a segment at the surface of a vitellus of nutrition. Hence the ovules of the *Tetranychus* enter into the class of those of which the segmentation is partial. (*Archives des Sciences, &c.*, t. xxxi, p. 104.)

Besides these original researches, M. Claparède submitted to us statements of the most striking advances which have been made in zoology and its kindred branches. Thus, he drew our attention to the investigations of M. Stein relative to infusoria, and to this unexpected conclusion, that the bourgeons of the verticelli are but an appearance resulting from the fact that a small individual has become conjoined with another of greater size. He analyzed the publications of M. Semper on the inferior animals which inhabit the coasts of the Philippine islands, and the new work of Dr. Darwin on the modifications experienced by animals in a state of domestication. He acquainted us with the recent observations of M. Parkes on muscular labor, according to which this labor would coincide, not with an oxidation of the tissue of the muscle, but with an augmentation of its volume produced by a more energetic assimilation of the nitrogenized substances with which the blood is supplied. M. Claparède explained (7th November) the ingenious researches of Prof. Max Schultze on the structure of the retina. According to this skillful micrographist, the two sorts of elements which are found unequally distributed in the exterior layer fulfill different functions. The rod-like organizations (*bâtonnets*) serve for the perception of the luminous intensity, while the cones are destined to distinguished colors.

Dr. Henry Dor made known to us that calabarine, the effect of which on the pupil is the reverse of that of belladonna, acts as an antidote to strychnine, by paralyzing the muscles which depend on the will without abolishing the latter. It may, therefore, be useful in tetanic affections. The professor last named gave his confirmation (2d April) to the fact, based on the investigations of Cramer and Reynolds, that the part heretofore attributed to the iris in the function of adjustment is completely null. It is the ciliary muscle alone which is in play.

Dr. Julliard the younger has had occasion to study a teratological case very rare in the human species, namely, *scironomelia*, or a soldering together of the two lower members. He presented to the society two photographs of the monstrosity, the subject of which lived some instants after birth, and gave a description of the anatomical peculiarities of the case.

Our vice-president, Dr. Lombard, read to us (2d April) the results of his sta-

tistical researches on the distribution of mortality in certain Swiss cantons, according to the months and seasons. At Geneva, where documents are extant which go back to the 16th century, it is ascertained that the difference from season to season has been but slightly sensible. The winter is the most unfavorable epoch, summer the most salubrious; spring approximates to the rate of winter, autumn to that of summer. Aubonne and Vevay furnish analogous results. In the canton of Neuchâtel winter is the most fatal season for the low country, while spring is most fatal in the mountain region. The same is remarked as regards 43 communes of the canton of Berne. Zurich, the city of Bâle, Thurgovia, Appenzell, show a slight predominance of mortality in spring. In Aargau winter has the highest range of mortality. Everywhere the cases of death are more numerous during the summer in cities, and during the winter in the country. The cold of winter is more homicidal as the altitude is higher; the ratio is reversed for the months of summer and autumn.

Such has been the scientific movement of our society during the year which finishes to-day. The variety of the subjects to which attention has been devoted equals their importance. I may congratulate my colleagues on the part which they have borne with so much zeal, a part which it is not for me to estimate, in the study, always novel and always attractive, of the phenomena of nature. Our cantonal and municipal authorities have recently added their efforts by creating at Geneva a museum, laboratories, and a library on a level with the progress of the age. Let us welcome cordially these new means of study placed at our disposal, and continue with ceaseless ardor to propagate the taste for intellectual pursuits. At the moment of resigning the functions which you have done me the honor to confide to me, I offer you, my highly esteemed and dear colleagues, the expression of my gratitude for the assiduous co-operation by which you have rendered the exercise of those functions as easy as agreeable.

HISTORY OF THE TRANSACTIONS OF THE ANTHROPOLOGICAL SOCIETY OF PARIS FROM 1865 TO 1867.

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[*Translated by* C. A. ALEXANDER *for the Smithsonian Institution.**]

When, four years ago, I had the honor of presenting to the society for the first time the analysis of its labors, I deemed it propér to preface my report by a brief historical exposition, in order to recall the principal phases through which anthropology had passed from its origin up to the epoch at which our society communicated to it a new impulse and direction. It was not at that time, perhaps, superfluous to show how the field of our science, restricted in the beginning to a purely descriptive study of the races of mankind, had become rapidly aggrandized when, renouncing the pretension of depending only on itself, it had contracted a close alliance with all the sciences which throw light on the past as well as present condition of humanity.

It is now nearly a half century since linguistics was called to lend its invaluable aid to ethnology. That indispensable means of investigation, whose reach extends much beyond the narrow outline of history, has revealed to us unexpected filiations and opened horizons almost without limit. In according it a large share in your labors you have but followed the example of your predecessors. But that which peculiarly pertains to you—that which you have for the first time realized—is the association of our science with geology and palæontology, with prehistoric archæology, with general natural history and zootechny, with medical geography, statistics, public hygiene—in fine, with physiology and medicine itself. To fulfill this gigantic programme, the society has invoked and obtained the co-operation of a great number of savants, differing in the nature of their studies, but all alike emulous of participating in the progress of the science of man. By the side of these, historians, men of letters, artists, philosophers, have taken their place, and by their communications not unfrequently enlightened our discussions. Thus human knowledge, in its most varied forms, finds its representatives among us, and our society is as a living encyclopedia, in which all questions, under every different aspect, may receive immediate consideration by competent minds.

This propitious state of things has, however, given rise to some criticism. Those who regard the objects of anthropology in a different light from ourselves, and who would restrict it to the description of human races, have conceived a fear lest among so many sciences which it has laid under contribution it should lose its unity of action, its independence, and, so to speak, its individuality. But it is enough to be present at any of our sessions to see that the ideas which are disengaged from the great variety in our labors always converge in the end towards the same object, and to realize that anthropology, far from being absorbed by the sciences which surround it, is, on the contrary, the common ground on which they meet—the focus which attracts and the bond which connects them. It is like those edifices in course of construction for which work-

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men of every order, from the artisan to the artist, bring together and arrange materials of all kinds—stones hewed or sculptured, exotic marbles, granite, wood, metals. To the apparent confusion of the first stage succeed, after a while, order and harmony; nor is it necessary to wait till the structure is finished to discover the plan and purpose of the architect. It is in like manner that the collective work of our society is developed; the architect here is an impersonal being, it is the society itself; and all we who respectively represent the numerous sciences summoned to its aid are the workmen, whose zeal it stimulates and whose labors it turns to account.

But the vast variety of subjects which enter into our programme has given birth to prepossessions which manifest themselves at recurring intervals. The necessity of drawing anthropological indications from all sources has been contested by no one; but it has been asked to what point and within what limits the sciences which group themselves around anthropology should be placed under contribution? Our distinguished colleague, M. Charles Rochet, who first suggested this question, has long studied human types under the artistic point of view. His attention has been particularly directed to the characters of Greek and Roman heads—characters which he has chiefly determined from antique sculptures, without neglecting, however, the testimony of numismatic or ceramic art. But at the moment of communicating to us the results of his curious observations, he has hesitated; he has felt a doubt whether researches of this kind, based on facts which pertain principally to the domain of art, ought to figure in the compass of anthropological investigations, and he has invited the society to state in a general manner the nature of the relations which it regards as established between anthropology properly so called and the conceptions which the latter borrows from different branches of human knowledge. The scruples of our colleague were exaggerated, and the interest with which you have listened since then to his memoir on the type of the Roman head must have satisfied him that they were so. But the general question which he had propounded retains all its importance, and merits your attention the more inasmuch as it was recently reproduced when M. Camus communicated to us the learned researches of M. Fétis on musical systems considered as an ethnological character,

The history of the arts, no more than that of languages, of religions, of letters, or political societies, no more than the sciences called biological, no more than zoology, palæontology, and geology, forms any part of the programme of anthropology. A memoir *ex professo* on painting or on music would be as little in place here as a communication on the structure of the bones, or a dissertation on the use of the subjunctive. Anatomy, however, furnishes us the best distinctive characters of the human races, and we are obliged incessantly to invoke its aid when we would establish a parallel between the human group and that of the anthropomorphous apes. Nor is linguistics less indispensable when we design to study the filiation of nations and races. Little does it import to us that such a race of sheep furnishes an abundant fleece, that such another affords less wool and produces more flesh; but when the history of these races, of their origin, of their crossings, of their degree of stability, supplies us with ideas more or less precise on the general question of the race or species, anthropology avails itself with eagerness of these facts, which are capable of contributing to the solution of some of its gravest problems. It is thus that we have often seen our learned colleague, M. Sanson, bring his vast knowledge in zootechny to bear, and never without effect, upon our discussions. We could not advance a single step in the study of the prehistoric races if archæology had not first furnished the elements for the distinction of epochs—if it did not indicate to us the relative dates of the inhumations from which we derive the bones submitted to our observation; yet it is evident that the labors proper to pure archæology would divert us from our object. This has been perfectly comprehended by those of our colleagues who, without ceasing to be numbered among our most zealous and active members,

have founded within two years past, under the presidency of M. Leguay, the *Parisian Society of Archæology and History.* In this younger association, which so many ties connect with our own, archæological facts are set forth in all their details and are discussed for their own sake, while among ourselves the archæological demonstration is, so to speak, but the preliminary of the anthropological facts which result therefrom; and hence it frequently happens that the same researches, without involving useless repetition, present themselves at the same time in both societies under different points of view. This example serves, better than any other, tc evince the nature of the relations of interdependence (*solidarité*) which exist between anthropology and the sciences grouped around it. It asks from those sciences indications rather than didactic developments, and therefore can afford to exclude none of the branches of human knowledge which are capable of furnishing any ideas on the history or the families of mankind.

Under this head I may point to the importance of the researches of M. Fétis, of Brussels, on the origin of musical systems, and their distribution among the different populations, ancient or modern, civilized or barbarian. This venerable savant has devoted a long life to a study which, previously, had barely attracted the attention of a few virtuosi, but which has become in his hands a real science. Accustomed from our infancy to certain musical impressions, we have been led to believe that our classical gamut is the sole form of harmony, that the division of the octave into five tones and two demi-tones is an institution of nature, and that every modulation whose elements do not enter exactly into this division is false, discordant, contrary to the pre-established order of things. This, however, is but an illusion developed by habit. It suffices to hear or to analyze the strains of the nightingale or linnet to perceive that they cannot be expressed on the keys of our pianos, and to be convinced that the purest harmony may exist outside of our musical system. As for this system, we find it everywhere among the nations which have adopted our own form of civilization. The multitude of strangers drawn to the Universal Exhibition at Paris, after having presented during the day the phenomenon of a complete confusion of tongues, constitute but a single people wher. they congregate at night in the saloon of the opera. Amid the diversity of their idioms, the music establishes between them common sensations, and, so to say, a common language; but if the same auditory found itself transported of a sudden into the presence of one of the Chinese orchestras with which our colleague, M. Armand, has lately entertained us, it would suppose that it was listening to a *charivari* and would stop its ears, much to the scandal of the indigenous spectators, who, for that matter, no more comprehend our musical system than we theirs.

Just as linguistics enables us to establish among the groups of mankind distinctions and approximations, the significance of which may admit of discussion, but whose reality is rigorously demonstrable, so the study of musical systems and of their actual distribution may furnish valuable indications, if not on the filiation of races, at least on the communications which must have existed between them at epochs more or less remote. For this reason alone, the comprehensive researches of M. Fétis would be worthy of your favorable attestation. The documents which he has collected on the music of nearly all modern nations have led him to establish a certain number of great and well-determined groups. But this conception, however interesting it may be, did not satisfy him. He perceived that it was necessary to seek in the study of the past the explanation of the present state of things, and has undertaken a labor which may be compared to that of the linguists who, resuscitating dead languages and even reconstructing primitive ones of which no recollection is retained, have succeeded in casting no obscure light upon prehistoric eras. Not content with recombining all written indications on the music of the ancients, M. Fétis has brought into play the instruments discovered by the archæologists. The flutes, the fragments of the lyre found in the monuments of Egypt or sculptured on Assyrian bas-reliefs,

have served him as models, and, by copying these instruments with his own hand and with strict exactness, he has drawn from them sounds which have restored to life musical systems buried in oblivion for thirty centuries. These remarkable researches require, no doubt, the control of criticism and the sanction of time, but it may confidently be said that even now they open to science a resource not only suggestive but wholly new. Not that we are to hope that the study of musical systems can ever acquire an historical and ethnological value equal to that of linguistics. Music is a mode of expression less rich and far less precise than articulate language, and can only furnish terms of comparison much more restricted. It is certain, moreover, that it is less closely connected with the life of the people, with their nationality, and the facts cited by M. Fétis himself prove that nations whose languages pertain to stocks entirely distinct have adopted the same musical system. But the means of investigation with which anthropology has been thus endowed are not the less valuable, since they reveal to us at once the artistic aptitudes of certain races and the communications which have been established between them in times previous to history.

I have thought proper to dwell somewhat on these researches, so new and so interesting, of which our society has enjoyed the first fruits, and which make, for the first time, their appearance in science. Arriving now at subjects if not more classic, at least more commonly known, I may restrict myself to more summary statements.

General anthropology has occupied, as usual, a large space in your labors. The question of the influence of climatic mediums which gave rise, three years ago, to so extended and complete a discussion, presented itself anew on occasion of the important memoir of M. Carlier on acclimation in America. No one could treat this subject more competently than the author of the *Histoire du peuple Américain.* Although his long researches have borne principally on the populations of North America, M. Carlier has also studied the acclimation of the negro race in the Antilles and in Brazil. That the races of the old world are acclimated in the States of the Union is demonstrated by the rapidity with which the population has there increased; but to appreciate the signification of this movement, it is necessary to distinguish the intrinsic increase from that which is due to immigration. This is what M. Carlier has done, and we cannot too highly praise the sagacity with which he has availed himself of all the statistical documents, unfortunately incomplete, which have been collected in the United States since the beginning of the century. From these laborious researches it results that the intrinsic increase of the population has sensibly slackened for 20 years past. The inquiries of our learned colleague have moreover established, contrary to the generally received opinion, that three-fourths of the immigrants are foreign to the Anglo-Saxon race. The ethnical importance of this fact is considerable. M. Rameau, struck, like many other observers, with the differences which exist between the English of Europe and the Anglo-Americans, has attributed these modifications to the influence of climatic mediums, while, according to M. Carlier, they are due principally to the influence of cross-breeding. The interesting discussion which arose on this subject between our two colleagues seems to have left the subject undecided as regards the 13 primitive colonies which, at the close of the last century, founded the American Union. But for the 23 States which have been formed since then, and several of which date but from yesterday, it is difficult to invoke a climatic influence which can only have been exerted on two or at most three generations. M. Carlier has insisted that the modifications produced by climate cannot be manifested in so short a lapse of time.

To complete his investigation, our colleague has studied the acclimation of the negro, not only in the United States but also in the Antilles and Brazil. This part of his memoir procured us some interesting communications from M. Martin de Moussy on the state of the negroes in South America, and from M. Simonot on the questions of hybridity suggested by the study of the mulattoes. If the

population of persons of color increases considerably in certain countries, it is not, according to M. Simonot, from its own fecundity but through the reinforcements it incessantly receives from continual crossings of the whites and blacks. To the numerous and weighty facts which M. Périer has brought together in his learned memoir on the cross-breeding of human races, and which authorize a doubt of the validity and fecundity of many hybrid populations, M. Simonot adds another which, according to his own observation, would oppose a still more decisive obstacle to the formation of mixed races: the tendency, namely, which, after the lapse of some generations, restores gradually the descendants of hybrids to the type of one or other of the mother races. These phenomema of atavism have become difficult to be distinguished from the effects of crossings in a recurrent direction, because hybrids of different bloods pair and mix on all sides, whether with one another or with individuals of pure race. But this complication can be easily avoided in experiments made upon the domestic animals: hence M. Sanson has been enabled to take his stand upon many precise facts in order to demonstrate the instability of the characters of hybrids. M. Pruner-bey pointed out, however, that conclusions drawn from the study of certain crossings might not be applicable to other crossings different from the former in the nature of the races or species, or in the conditions of the medium in which they are effected.

It is very probable, in effect, that these different circumstances have an influence on the results of cross-breeding. It is necessary, above all, to take account of the degree of proximity of the races; and what results most clearly from the researches of M. Périer is, that the disadvantages of cross-breeding are the more decided as the two mother races are more unlike. If the similarity of the parents constitutes a favorable condition, it is natural to think that, all things else being equal and abstraction being made of hereditary pathological influences, consanguineous unions cannot become detrimental from the sole fact of consanguinity. It is thus that M. Périer has been logically led to connect the opposite, but yet reciprocally dependent, questions of hybridity and consanguinity.

These two questions have, from the origin of the society, given rise to a great number of memoirs and discussions in which contradictory opinions have been brought to light. But I should speak here only of the facts which have been adduced within two years past. I shall not recur, therefore, to the debates which were maintained some years ago, between MM. Boudin and de Rance, adversaries of consanguineous unions, and MM. Bourgeois, Périer, Dally, who denied the harmfulness of those unions. No one contested the reality of certain facts alleged against consanguinity; all acknowledged that in families infected with constitutional vices or hereditary diatheses, marriage between cousins leads to unfortunate results; but these results were attributed by the one party to the consanguinity itself, while the other considered them but as a particular case of the accidents of inheritance. These last gave expression to their opinion by saying that *healthy* consanguinity is exempt from bad effects. The question being stated in this form, it was no longer competent to seek here and there for sporadic examples which might appear more or less favorable to one or the other thesis. To avoid the chances of error resulting from individual accidents, it was necessary to study the effects of consanguinity in some restricted and well-circumscribed populations, in which unions between relations are habitual. This has been done with the greatest precision by our colleague, M. Voisin. The commune of Batz, situated on a small peninsula north of the mouth of the Loire, comprises a population of 3,300 souls, devoted exclusively to the cultivation of the salt marshes. The special nature of this industry offers little attraction to strangers; hence it is very rare for an inhabitant to marry beyond his commune, while consanguineous unions, even within the degree prohibited by the church, are extremely frequent. Thus, in the year 1865, there took place between cousins-german or their issue 15 marriages, for which it was necessary to ask ecclesi-

astical dispensation. It was in the midst of this consanguineous population that M. Voisin collected his observations. He did not content himself with verifying in a general manner the physical prosperity of the inhabitants. He has recorded the history of each household, examined the parents and children, studied the births and deaths, and in a word prepared very complete genealogical tables, in which is summed up all the information relating to 46 consanguineous marriages. In studying these tables, published at the end of the memoir, we cannot help recognizing with M. Voisin, that in a healthy population, consanguinity, even when superposed, involves none of the deterioration which has been attributed to it. After having sojourned at Batz an entire month, and passed in review all the families, our colleague has ascertained that "neither vices of conformation, mental maladies, idiocy, cretinism, surdo-mutism, epilepsy, albinism, nor blindness from pigmentary retinitis, exists in any individual, whether the issue or not of consanguineous parents."

Analogous observations have been collected by M. Dally in the little isle of Bréhat, (Côtes-du-Nord,) and by M. Duchenne of Boulogne among the population of Portel. They are less rigorous, indeed, than those of M. Voisin, since they are not accompanied by genealogical tables, but they are still very important; they are moreover confirmed by the zootechnical observations of which M. Sanson has presented us a summary, and which are due to M. Renard of Issoire, and M. Legrain of Brussels. M. Legrain has especially turned his attention to the production of albinism in rabbits; it results from his experiments, divided into several series and conducted with great sagacity, that consanguinity never produces albinism among those animals when they are reared under good hygienic conditions; but that albinism manifests itself at the end of some generations when the rabbits are ill-fed and lodged in dark and unclean warrens. Nothing could better justify the distinction advanced by M. Périer between healthy and morbid consanguinity than this example.

The questions of consanguinity and hybridity, and the discussions to which they have given rise, naturally lead me to consider the numerous communications of M. Sanson on the characteristics of race and of species. It is, in effect, the study of the phenomena of generation, direct or crossed, which serves as a basis to the doctrine sustained with so much conviction by our colleague.

The authors who have occupied themselves with the determination of species may be divided into two classes: one, and by far the more numerous class, makes specific distinctions rest on the *ensemble* of the morphological and anatomical characters; the other, after the example of Ray, Buffon, and M. Flourens, admits as a criterion of species only one sole and unique character purely physiological, namely, the perfect fecundity of sexual unions. M. Sanson accepts at once both these zoological methods, which heretofore have disputed the suffrages of savants; he holds them both as valid, but applies them to different cases. He employs the physiological method for constituting the group called *species*, and avails himself exclusively of the anatomical method for the determination of the *races* of each species. These races are not, in his view, varieties resulting from the subdivision more or less tardy of a species previously uniform and homogeneous. They are primordial, or, in other words, as ancient as the species itself; they are moreover permanent and immutable; that is to say, neither the influence of climatic mediums, nor crossings, nor selection can cause them to deviate in a durable manner from their primitive type. In other terms, as M. Lagneau has expressed it, M. Sanson attributes to each of the races which compose a species the properties and characters hitherto attributed by classic naturalists to the species itself; a sense which M. Sanson himself elsewhere conveys in saying that it was his object "to introduce a substitution of *race* for *species* as the last term of natural classification."

The doctrine of our colleague is in the end, therefore, but an emphatic and absolute form of polygenism. But the discussion to which it has given rise in

this society has turned only upon general principles, and the special question of the permanance of human races has not been broached. While M. Gaussin contested the value of the exclusive physiological character on which M. Sanson relies for the determination of species, MM. Lartet and Lagneau suggested doubts respecting the absolute permanence of races, and cited facts tending to demonstrate the formation of new races in domestic species, and even in wild species; and M. de Mortillet, relying chiefly on paleontology, went so far as to deny not only the permanence of races, but also that of species. The convictions of M. Sanson have not, however, been shaken by these objections, and his opponents themselves have acknowledged the talent which he has displayed in this difficult line of inquiry. Questions of this class are among those which will be long, doubtless, the subject of controversy; but the discussion elicited by M. Sanson has not been without its fruits: it has shown, in the first place, that the standard idea of species, considered as a natural, primordial, and permanent group, is far from sufficing to the actual needs of science; it has shown also that races to which it has been the custom to attribute a variability much too great, tend, on the contrary, for the most part, to maintain and perpetuate themselves without durable change; that the innumerable varieties obtained by crossings, selection, or culture have in general only a factitious existence, and that, left to themselves, they disappear if not always, at least almost always, whether from the want of fecundity or from the effect of the law of atavism, which, after a while, causes types momentarily effaced to reappear.

I must pass in silence, but not without regret, a considerable number of ethnological facts, simply descriptive, which would lead to analytic details of too special a nature. As a subject of more commanding interest, and one which has always asserted a paramount claim to the attention of the society, I proceed to notice its discussions respecting craniology.

As the skulls presented to the society and destined to enrich its museum become more numerous, the more need is manifested of a recurrence to rigorous processes of measurement in order to institute truly scientific comparisons between the different series. For geometric diagrams, for angular measures and triangulations, special instruments are indispensable; they enable the observer to detect shades of difference which would otherwise escape the most practiced eye, and furnish moreover numerical data for the calculation of mean terms. Hence the commissioners to whom the society has intrusted the charge of preparing instructions for craniometry have applied themselves particularly to the improvement of instruments for study. They have already presented us a new goniometer, light and not costly; a new craniograph qualified to delineate completely, by way of geometric projection, all the details of the surface of the cranium; and a small and very simple instrument, the sphenoidal crotchet (*crochet*), by means of which the sphenoid angle of Welcker may be measured without sawing the skull. Our colleague, M. Grenet, (de Barbezieux,) has also communicated a new process of triangulation of the skull and face, an ingenious expedient, the utility of which has been shown by M. Bertillon in his dissertation on cephalic angles. In this memoir, in which are collected all known facts relating to the facial angle of Camper and its derivatives, as well as the auricular angles and the angle of Welcker, M. Bertillon has recorded moreover the numerous observations made by himself on the different series of our museum, and has pointed out all the advantages to be derived from the judicious employment of statistical calculations, for correcting the errors or rather the divergencies which result from the diversity of the processes of mensuration.

It was not the first time that the results of craniometry had been submitted before the society to the correction of mathematical methods. M. Gaussin had already applied algebraic formulas to the determination of the relations which exist between the three diameters of the skull, and had expressed these relations by the help of graphic constructions based on the system of rectilinear co-ordinates.

Taking as a point of departure the measurements which he had executed on the great series of crania known by the name of *skulls of the city*, he deduced a formula which he has since tested by its application to the craniometrical tables prepared, from series the most diverse, by M. Pruner-bey, by MM. His and Rutimeyer, and by myself. Now, such is the precision of his calculations, that in every case where the formula applied to series of skulls of the same type appeared to indicate divergencies, it has been ascertained that these depended on the difference of the processes employed by the different observers for the measurement of the vertical diameter. The way opened by M. Gaussin in this remarkable memoir may be easily enlarged, for all the craniometrical elements may be made auxiliary to the same researches; nor can it be necessary to point out the importance of a method which permits of reducing to the same standard observations collected according to different processes, and even of correcting what astronomers call the personal error.

Our distinguished colleague, M. de Khanikof, also, bringing to the study of anthropology the aid of the exact sciences, has successfully applied the formula of M. Gaussin to the cephalometric measurements reported from Persia by M. Duhousset, who, operating on the living man, had only been able to obtain by approximation the length of the vertical diameter. In conformity with the general instructions published by the society, M. Duhousset has taken, to replace that diameter, the height of the plane of the vertex above the auditory orifice. But the situation of this orifice in relation to the plane of the base of the cranium sensibly varies according to races. We might expect, therefore, to recognize a certain divergence between the results of the cephalometric observations of M. Duhousset and the craniometric formula of M. Gaussin. This divergence has, however, proved very small; in four out of six series of observations the result has been less than one millimeter and a half. The two series of Kurds and Hindoos alone have presented divergencies of three and four millimeters, which depend, doubtless, on variations in the position of the auditory canal. On this occasion M. Khanikof communicated to us the notes which he had collected in the museum of St. Petersburg on the height of the orifice above the plane of the occipital orifice. He has consigned them to a valuable table, in which figure most of the populations of Asia.

But it is impossible to speak of craniometric tables without immediately recalling those with which our former president, M. Pruner-bey, has enriched our *memoirs* and *bulletins*. Thanks to him, we can now pursue, in the closet, the most precise study of the constitution of the skull and face of the greater number of the human races. The three great tables which accompany his memoir, entitled *Résultats de crâniométrie*, comprise more than 15,000 measurements taken on skulls derived from all quarters. Among them we find 117 African skulls, 165 from Oceanica, 82 American, 58 Asiatic, and 105 European skulls, ancient or modern. It would be in vain to seek elsewhere an equal amount of documents collected after uniform processes by the same observer. These three tables present us, in a condensed form, the results of many years of circumstantial researches, and when we think of the immense labor they have cost we cannot but wonder how our colleague has found time to execute his great works in linguistics, and to treat, moreover, with so much competence the highest questions of general and philosophic anthropology. The secret consists in his having enjoyed the happy privilege of preserving, in the maturity of age, the indefatigable ardor and the sacred fire of youth. Let us add that he is one of those rare men of science who have the good fortune to be able to devote themselves entirely to the study, or rather the religious culture, of anthropology. May the example he gives us find frequent imitators!

It is not here that I can hope to recapitulate all the craniological facts which have been communicated to the society. Rare it is for a single sitting to pass without an offering of new skulls. Among those which have come from foreign

countries I shall content myself with mentioning the skulls of two Chellouks, inhabitants of the banks of the Nile, presented by M. Lagarde; the two skulls of Red-skins, brought to us by M. Berchon; the cranium of a Bechuana, sent by M. Lautré, missionary in southern Africa; the Egyptian head, and the skull of an Arab, which we owe to M. Périer; the curious deformed skull from the valley of Ghovel, (Central America,) which the Abbé Brasseur de Bourbourg has contributed to our stores; finally, and above all, the magnificent head of an Australian, conveyed to us by Professor Ch. Martius. This last piece, so remarkable in an osteological point of view, reveals to us a singular and heretofore unknown trait of Australian manners. It is mummified; all the flesh of the head, desiccated and hardened to an extreme degree, is applied exactly to the bones; the half-opened mouth is filled with bird's feathers; a string strongly knotted is passed through the cartilages of the nose. From what is known of the customs of the Australian tribes it is impossible to suppose that this head proceeds from a body embalmed or mummified by a methodical process. Everything leads to the conclusion that it is a trophy of war, dried and preserved as a memorial by the victor in some bloody affray.

A particular notice is due to two fine series of skulls collected in Syria by M. Girard de Rialle, and at Alexandria by our regretted colleague, Schnepf. The skulls from Alexandria date from the Greco-Roman epoch. The population of that great city then presented a confused mixture of nearly all the races of the ancient world. Hence the practiced eye of M. Pruner-bey has been able to detect in the collection of M. Schnepf, besides the skulls of Egyptian race, a still greater number of those of Greeks, Romans, Ligurians, Negroes, and Syrians. The skulls of the collection of M. Girard de Rialle are derived, some from Damascus, the others from Rasheya. These last, to the number of 12, present a surprising uniformity, and appear to have been artificially distorted by an occipital compression.

The European skulls presented have been too numerous to admit even of mention. Most of them are referable to the man of the prehistoric era, or to certain existing populations which appear to be the issue of the primitive race of the age of stone. The conquering races which introduced into Europe the Aryan languages and the use of metals did not destroy, as may have been supposed, the vanquished nations, but, by mingling with them, caused them to undergo, almost everywhere, modifications more or less profound. Since that period new crossings, many times superposed, have changed more and more the character of the first races; new conquests, new migrations have, in some sort, transformed the greater part of the populations of Europe, and, in the midst of this almost inextricable intermixture, the exploration of ethnic origins has become one of the most complicated problems of our science. To dissipate this uncertainty two principal means lie open before us. These are, on the one hand, the study of those populations which, according to the testimony of linguistics, have more or less resisted the foreign influence, and which, in preserving their pre-Aryan languages, have doubtless also preserved, in a degree of relative purity, the type of the primitive races; and, on the other hand, the examination of the remains which the populations of the age of stone have left in the soil, at prehistoric epochs whose succession has been determined by archæology and palæontology.

The surviving witnesses of the primitive human fauna of Europe form now only two groups, confined to the two extremities of that part of the world, and resembling those summits still existing under the shape of islets in submerged regions—they are the Basques and the Fins. Our distinguished colleague, M. de Baer, thought that he had discovered among the Romans of the Rhetian Alps a third group of primitive populations; but this opinion, already refuted by MM. His and Rutimeyer in their *Crania Helvetica*, cannot sustain itself in presence of the facts embodied in the two important memoirs which M. His has addressed to this Society. The brachycephalous population of the environs of Coire, far from

being representatives of the autochthonous race, are, on the contrary, descendants of the *Alemani*, the last invaders of the country. The attention of the Society has been therefore principally fixed on the Fins, with whom we may associate the Esthonians, and on the Basques.

M. Beddoes, (of Clifton,) well known for his researches respecting the populations of Scotland and Ireland, has communicated to the Society the table of measurements which he has taken of the heads of the Swedes and Finns. The last are distinguished by a decided brachycephalism, and differ from the Scandinavians not less by the conformation of the face than by that of the head. The absence of the Finnish skull constitutes in the museums of Paris a void much to be regretted. Last year, however, three skulls of Esthonians were given by M. Baer to the museum of natural history, and have been the subject of an important communication of M. de Quatrefages. Although separated from the Finns by the Gulf of Finland, the Esthonians speak a dialect of the same language, and, notwithstanding the mixtures they may have undergone, the greater part of them still preserve the characters of the Finnish race. Of the three skulls which M. de Quatrefages has presented to the Society, one is purely Mongolic; the second is so too, though in a less degree; both are brachycephalous. The third is almost dolichocephalous, but is very similar to the second in the form of the face; like that, it is remarkable for a prognathism limited to the upper jaw. The lower maxillaries, on the contrary, have a vertical direction, and M. de Quatrefages has discovered in those bones all the characters of the famous jaw of Moulin-Quignon. Our eminent colleague is hence disposed to believe that the Esthonians are the remains of a race heretofore disseminated in western Europe, where it has long since disappeared through multiplied and predominative crossings, but where, nevertheless, it has left an influence which is still manifested here and there by the phenomena of atavism. The cases of alveolar prognathism which sometimes present themselves among our own people, especially in females, would thus find an explanation. These views, resting thus far upon but two pieces, (for the first Esthonian skull, being toothless and deprived of the lower jaw, cannot serve for the study of prognathism,) have need of further confirmation; but they are not unworthy, even now, of being regarded with high interest.

As to the Basque skulls, the discussions to which they have given rise in the society are still pending. Nineteen new skulls, similar in all respects to the former 60, and, like them, nearly all dolichocephalous, have been sent to us by our zealous colleague, M. Velasco. But these, again, come from the cemetery of Zaraus, and do not escape, consequently, the exclusion invoked by M. Pruner-bey. Every effort should be used, therefore, to procure Basque skulls from some other scene of production. The consignment made by M. Velasco had the advantage, however, of eliciting a new discussion, which procured us the pleasure of hearing an instructive lecture of M. Pruner-bey on the Basque language. Without disavowing the analogies which have been pointed out between that language and the Tartar idioms, our colleague shows that these analogies are superficial and of little significance. In his view the Basque language constitutes a unique fact in the old continent, and has true affinities only with the languages of America; but he does not think himself authorized, from the affinity of the languages, to infer the filiation of the populations. However this may be, the ideas set forth in this memoir are but little favorable to the hypothesis of those who strive to reduce to one single race all the primitive, or rather pre-Aryan, races of Europe.

This question of prehistoric races, thanks to the zeal of the archaeological anthropologists, has made, within a short time, remarkable progress. France, Switzerland, Belgium, the British Isles, Scandinavia, are no longer the only countries subjected to the investigations of our science. There is now scarcely any country of Europe which is a stranger to researches of this nature. More than one important prehistoric station has been discovered in Germany and Austria.

The publications of the anthropological section of Moscow have made us acquainted with excavations effected in the old tombs of Greater Russia. In fine, recent and numerous explorations made in Italy, in Spain, in Portugal, have shown, beyond dispute, that the two occidental peninsulas have also had their age of stone. The results of the first researches of Casiano de Prado were stated to the Society by M. Pruner-bey in an interesting report on *Anthropology in Spain*. The discoveries of that savant, too soon lost to science, have been confirmed by M. Edouard Lartet, the worthy son of our eminent colleague. M. Pereira da Costa, moreover, has communicated the facts which relate to the antiquity of man in Portugal, chiefly in the basin of the Tagus. This is doubtless but a first harvest. The ideas which we possess respecting the primitive populations of Iberia are as yet too vague to furnish grounds for a synthesis; but facts more numerous and more precise, collected in the other peninsula, have shed quite a new light on the primitive conditions of the country. A Nicolucci, an Italia-Nicastro, a De Rossi, a Gastaldi, a Cocchi, a Canestrini, emulous in zeal and perseverance, have shown what science may hereafter expect from regenerated Italy. The Phœnician sepulchers of Sicily and Sardinia, explored by M. Italia-Nicastro, have furnished a large number of highly interesting archæological facts. M. Nicolucci has sent us the description and figure of several of the skulls which have been obtained; and when these skulls are compared with those which are procured from the ancient tombs of Etruria we feel authorized to predict a day when the Semitic origin of the Etruscans will be definitively demonstrated. It is to M. Nicolucci, moreover, that we owe the first craniological ideas on the ancient Iapyges, a population of southern Italy, of whom the historians of antiquity have made but vague mention, and whom it was the custom, not very long ago, to regard as autochthonous. M. Mommsen had already surmised, from inscriptions on their tombs, that certain characters distinguishable in the remains of their language tended to ally them with the Indo-European group of nations. This view has been now fully confirmed by our learned colleague, M. Nicolucci, who, having had an opportunity of studying three skulls found in Iapygian tombs, has authenticated their resemblance to the Greek type. Collating this idea with the historical vestiges which he has been able to collect, he is led to think that the Iapyges were a horde of Pelasgic origin, chased from Greece into Italy by the invasion of the Hellenes. This is still but an hypothesis; but what appears almost certain is, that the Iapyges were of foreign origin and that they were not the first occupants of the peninsula. If the Iapyges and the Etruscans are to be considered as exotic branches, where shall we find the primitive races of Italy? The question, in as far as southern Italy and Sicily are concerned, is still very doubtful. The facts which M. Rossi has recently detailed to us with so much clearness establish the existence of a dolichocephalous population which occupied central Italy during that age of stone, which the poets, with perverse inspiration, have called the age of gold. But in northern Italy, in the ancient Liguria, there was a brachycephalous race, which appears to have preceded all the others. This Ligurian race, which has been made known to us by the labors of M. Nicolucci, extended on the Mediterranean coast as far as southern France. Our illustrious colleague, the Duke de Luynes, has made many explorations in the soil of these regions; he has exhumed a great number of skulls, which M. Pruner-bey has exhibited to us, and in the greater part of which he has pointed out the characters of the Ligurian race.

It is here that I might introduce the facts relating to the anthropology of France, but these are to be the subject of a special report, which you have confided to the learned pen of M. Lagneau. I cannot dispense, however, with a grateful recognition of our obligations to the activity and generosity of our archæological colleagues who, not content with enriching our bulletins with their interesting communications, have endowed our museum with a great number of articles the more valuable for having their authenticity and date guaranteed by com-

petent authorities. Thus, MM. Bertrand and Leguay have procured for us a whole series of skulls and bones taken by themselves from the dolmen of Argenteuil, and M. de Saulcy has given us several skulls derived from the tumuli of Meloisey, (côte d'or,) and which date from the first age of iron. The Society has also received, thanks to the intervention of several of its members who formed part of the commission of the museum of St. Germain—thanks especially to M. Bertrand, director of that museum—a fine series of skulls exhumed from the Gaulish cemetery of Saint Étienne-au-Temple, near Chalons-sur-Marne. Sundry communications of M. Roujou and M. Leguay have brought to our knowledge the results of the excavations made at Villaneuve-Saint-Georges, in a station of the age of polished stone. M. Roujou has superadded the description of a number of specimens of cut silex found in the diluvium of the environs of Paris, and of several hearths engaged in the loess near Choisy-le-Roi. M. Mauricet has presented to us bones extracted from the dolmen of Moustoir-Carnac, (Morbihan,) and the fac-simile of two human feet delineated on one of the lateral stones of the dolmen of Mont-en-Arzon. If we add to these the fine head from Quiberon, sent by M. de Closmadeuc, (of Vannes,) and the cut silex which MM. Hamy and Sauvage have brought from Chatillon, near Boulogne-sur-Mer, we shall still be far from having enumerated all the archæological facts which relate to the anthropology of our country. But I should hardly be pardoned for quitting this subject without mentioning in a particular manner the numerous communications of M. de Mortillet on the prehistoric epochs. The learned editor of the *Matériaux pour l'Histoire Positive et Philosophique de l'Homme* leaves us not in ignorance of any of the important facts which throng from all quarters to his journal, and if we are ever at a loss for information we are sure of finding it with him.

The greater part of the archæological documents of which I have just spoken relate to the epoch of polished stone, which preceded the age of bronze; that is to say, the inauguration of the Indo-European era. The ages which afterwards elapsed till the advent of written history, and which are designated by the name of the Celtic epoch, are accessible by several means of investigation. Anthropology relies not here solely on archæology; it derives light from the torch of linguistics, and even from the first glimmerings of history. A note of M. Henri Martin on the Cimmerian migrations, a learned memoir of M. Georges on the origin of the Celts, have added new facts to those which found a place, three years ago, in the discussions of the society on the original sources of the European populations. On the other hand, our venerable foreign associate, M. d'Omalius d'Halloy, whose green old age sets at naught the ravages of time, has maintained, in a remarkable and highly applauded work, the objections which he had previously raised against the prevailing doctrine; and it is impossible not to recognize that, if linguistics be in a position to demonstrate the Asiatic origin of the Aryan languages, anthropological observation does not permit us to consider all the populations which to-day speak those languages as descendants in a direct line of one and the same people. The diversity of types of the modern Indo-Europeans can only be explained by the survivorship of autochthonous populations, which, already differing at the epoch of the Asiatic invasion, have been crossed with their conquerors, and have maintained the dissimilarity of races even where the relationship of idioms seemed to indicate a common origin.

The multitude of the races of prehistoric Europe, which forces itself on the mind as the necessary explanation of the actual state of things, results directly and incontestably from the study of the skulls of the age of stone. In the discussion which has been raised on the craniological type of the men of that epoch, facts apparently contradictory and yet perfectly reconcilable have been laid before the Society. On the one hand, it has been established that a very great majority of the skulls of the dolmens are dolichocephalous, contrary to the opinion of Retzius. This is true, not only for France but also for Great Britain, and very probably even for Sweden, the country of that celebrated naturalist; for it will

be recollected that the 20 skulls taken by MM. Van Duben and Retzius, jr., from the megalithic sepulchre of Luttra, in West Gothland, were all dolichocephalous, with the exception of a single one. On the other hand, however, the researches already mentioned of MM. Nicolucci and Pruner-bey establish with entire clearness the brachycephalous character of the race which, before the era of metals, occupied Liguria and the coast of Provence. At the era, then, of polished stone Europe already bore on its soil at least two distinct races. But those times which preceded all our histories, and which seem now so remote from us, appear, on the contrary, almost recent when opposed to the incalculable periods which palæontology has revealed to us, and which, terminating with the epoch of the reindeer, reascend even to the epoch of the elephant, the rhinoceros, the great bear of the caves, and probably still higher, without our being able to fix the limit to which ulterior discoveries shall carry back the origin of human kind.

During the first years of its existence, the Society of anthropology had occasion more than once to submit to study the question of the antiquity of man. At present, all discussion on this subject would be idle. The existence of the fossil-man, of the man of the quarternary period, cotemporary of the great pachydermata, is a fact definitively verified by science. If some protestations are still raised here and there against the evidence, it is not among us that they originate. I have made a small collection of works which have been published in France, in the 19th century, against the heresy of the rotation of the earth. Can we hope that the discovery of M. Boucher de Perthes should find more favor, in certain quarters, than the discovery of Copernicus? Leave we then, as the Scripture says, the dead to bury their dead, and let us pursue our work without occupying ourselves with the attacks directed against us by men of the past.

We, too, love the past; but above all we love to study it, and it is not our fault if the records of the past extend far beyond the limits which it has been customary to assign to them. Our curiosity is no longer content with knowing whether there were men on the earth in palæontological times. It asks what was the social state of those men; what their physical characters; whether they already constituted several distinct races; whether they differed from those who still later learned to polish stone; and, finally, whether the immense period which elapsed between the epoch of the mammoth and that of the reindeer, between that of the reindeer and that of the dolmens, did not see, like the infinitely shorter periods which have succeeded them, the human fauna of quaternary Europe ofttimes renewed and revolutionized by great movements, migrations, and conquests of the populations then existing? These questions of so high an interest are still far from a solution. Nevertheless, many important data have been already obtained, and justify us in presaging for a future, not far distant, satisfactory responses.

As regards industry, represented chiefly by instruments of silex, M. de Mortillet has shown us that it made gradual advances during the ages in question. In the lower deposits of the diluvium of Abbeville the axes are lance-shaped, and have been cut with rude and heavy blows, forming large fragments. In the argillaceous-sandy stratum which covers the diluvium, which is consequently more modern, and in which no bones of the mammoth have been discovered, the axes are elliptical, much elongated, and were cut with light blows, leaving small fragments. Finally, in the superficial stratum called the movable or loose formation of the slopes, the axes are polished, wedge-like, and similar to those found in the dolmens. Were these successive modifications of the same branch of industry attributable to gradual improvements or to the arrival of new populations? The memorable discoveries of M. Lartet, those especially which he has made in the caverns of Perigord, with the co-operation of our regretted colleague, Christy, authorize us to consider the latter supposition as highly probable. The inhabitants of Perigord possessed only cut silex; but they had reached a state of civilization and of artistic development altogether surprising. It is hard

to conceive how men destitute of the use of metals were able to fabricate of bone, ivory, the antlers of the reindeer, an infinite variety of very delicate utensils; to carve, I had almost said to chisel, elegant forms, and to represent by designs engraved in line on the handles of their instruments the figures of different animals. These figures are distinguished by an exactness and artistic skill truly remarkable, and to find in an equal degree the sentiment of art it would be necessary to revert, through many centuries, to the better times of Greece. They form a contrast so absolute with the rude delineations traced on some Celtic monuments, that it might be asked whether they have not been designed since the historic era, by fugitives who may have sought refuge in the caves of our ancient troglodytes. But what other than the man of the quaternary period could have designed in Europe, on the bones or horns of the reindeer, the figure of a species of elephant which differs from all living species? This race of men, so interesting through its civilization, led a peaceable existence. A skull found in the grotto of Bruniquel, of which M. Brun has sent us the photograph, is distinguished by the purity of its form, the softness of its outlines, the little prominence of the apophyses, the slight depth of the muscular insertions; characters incompatible with the violent habits of a savage or barbarous race.

What, then, became of this indigenous civilization, so original, so different from all those which are known to us? Was it modified by slow degrees and transformed to the extent of becoming at last wholly unrecognizable? No; it has disappeared in the mass without leaving any trace, and everything tends to the belief that it perished by force. After it, without transition, we find only the impress of a powerful race, religious and warlike, furnished with improved arms and familiar with the polishing of silex, but otherwise little addicted to industry and altogether alien to the notion of art. There are here all the indications of a brutal and successful invasion. The troglodytes of the age of stone, who had learned to conquer the soil and to destroy the last remains of the great mammals of the quaternary fauna, knew not how to defend themselves against the irruption of the barbarians, and an intermediate prehistoric age was interpolated as successor to the bright epoch of a premature civilization, whose origin is thus far wholly unknown.

These men of the age of the reindeer, so much advanced in certain respects were probably the descendants, but the softened and cultivated descendants, of the rude savages of the epoch of the diluvium. Oftener than once, in the soil of the same caverns, the lower strata are found to have enclosed the remains of the rhinoceros and the mammoth, while the superficial layers contained only the relics of the reindeer. The industry of which silex constituted the material had, from the first to the second epoch, been a little modified, but not transformed; and if a more regular cutting, with small fragments, had replaced the more rudimentary execution of earlier days, it was still by pure and simple percussion, without any process of abrasion, that the silex was elaborated. These changes moreover scarcely appear except in the fabrication of the axes; the knives continued to present a remarkable uniformity. It is probable, in fact, that the art of design was already known to the cotemporaries of the *Ursus spelæus*. This would appear at least to result from the curious figure which that indefatigable explorer of the caverns of the Pyrenees, M. Garrigou, has discovered on a silicious stone, taken by him from a grotto containing fossil bones. This figure represents a bear which, in the length of the spinal apophyses of its neck, resembles more the bear of the caves than any other species of the same animal. If the interpretation of M. Garrigou be confirmed, it will be interesting to have thus found the origin of the art of design among a race, susceptible, no doubt, of improvement, but which, at the epoch in question, was half-savage, and which perhaps was still committed to the practice of anthropophagism. M. Garrigou, in effect, and M. Roujou after him, have exhibited to the society several human bones on which are seen the traces

of methodical percussions designed to open the medullary canal and permit the extraction of the marrow.

Thus we have arrived at the most ancient known epoch in the life of mankind. What were at that time the physical characters of man? The bones of the members which have been found prove that the stature was of little height; and though the skulls or remains of skulls are still quite rare, it may be considered as very nearly demonstrated that our predecessors of the quaternary had the head small, with retreating forehead, and oblique jaws. But a graver and more critical question here presents itself. Our young, but already distinguished colleague, M. Dupont, in the excavations which he has conducted during several years for the Belgic government on the banks of the Meuse, between Liege and Namur, discovered, several months ago, among the bones of the rhinoceros and mammoth which occupy the lower stratum of the cavern of Naulette, a strange jaw, the zoological characters of which might at first seem to be equivocal. From its general form this skull appeared human, and was so in effect; but in the details of its conformation, its excessive thickness, the total absence of the prominence of the chin, finally and chiefly, in the character of the dentition, which is a character of the first order, it deviated considerably from the human type, while approximating to that of the anthropomorphous apes. Analogous traits, though less decided, had been already recognized in the jaw extracted by the Marquis de Vibraye from the cavern of Arcy-sur-Aube, the authenticity of which is not now to be questioned. In order to find in our actual humanity some of these characters, and even then much mitigated, it is necessary to descend to the lowest types of Australia and New Caledonia. The latter, it would follow, form not, as had till now been supposed, the last, or if you like, the first term of the human series. The quaternary man takes his place below them, and thus diminishes the interval which separates man from his zoological neighbors. But what is the signification, the import, of this fact? Must we recognize in this a proof of the transformation of species, or only a proof of the serial distribution of organic forms, of which the Darwinian theory is but a hypothetic explanation?

This doubt still subsists, notwithstanding the discussions to which so grave a subject could not fail to give rise. If it were demonstrated that the type of the man of Naulette, by successive and secular modifications, had been gradually improved so as to be elevated to our own, it cannot be dissembled that this would afford for the Darwinists a very potent argument. But do we know in what manner the quaternary races have made place for those of following ages? What is there to prove that the succession of types has not been the consequence of a substitution of races? Do we not now see, at many points of America and Oceanica, this substitution going on; the races of Europe taking the place of the indigenous races? Let us avow, then, that as yet the facts we possess are too few to solve this vast problem of the origin of the human kind, and let us wait till new discoveries bring us more numerous and decisive indications. The truth, whatever it may be, need not disquiet or humiliate us. Whether man has received his royalty as a congenital appanage, or valiantly conquered it after a long series of evolutions and struggles, does he not always remain master of the earth? He who knows how to manage as a docile instrument the blind forces of nature, who makes of electricity his messenger, who weighs the planets, and analyzes by photochemistry even the substance of the sun—will it be for him to blush at any revelation respecting an origin buried in the immeasurable depths of the past? No; the discussion in this Society, so complete, so conscientious, so learned on the doctrine of the human kingdom, sustained with so much ability by MM. Pruner-bey and de Quarterfages, sufficed to show that man, to maintain his rank in nature, has no need of undervaluing or degrading the beings which surround him. All the speakers, without exception, recognized the intelligence of animals, and discerned in them the germ of intellectual faculties, of sentiments and passions, which have acquired their full development, their full expan-

sion, only within the circle of human society. If MM. Alix, Rochet, Voisin, signalized, under different points of view, the superiority, uncontested as it is, of man, MM. Sanson, Letourneau, Simonot, Roujou, Gaussin, and others pleaded, with not less conviction, the cause of animals. The disputation, it is true, turned only on a single character, on that which henceforth will serve exclusively as a basis for the conception of the human kingdom, on the religious sentiment. It imported first of all to know whether this sentiment necessarily exists among all the tribes of men; whether it is sufficiently universal to serve as the characteristic of humanity. While MM. Quatrefages, Pruner-bey, Martin de Moussy, have no doubt of this, the opposite thesis was sustained by MM. Prat, Letourneau, Dally, Coudereau, and Lagneau. Let us not be surprised at these divergencies of opinion, inseparable from a subject which connects itself with all the most arduous questions of psychology. But let us recall with satisfaction that in this interesting debate, in which everything was in play that might rouse the feelings, and opinions the most contradictory found the utmost freedom of expression, no germ of discord was allowed to take root. Every one proved himself capable of respecting the convictions of his neighbor, and urbanity of language, the consequence of reciprocal esteem, constantly sustained the discussion at the level of the serene heights of science.

I am very far from having finished, and yet it is necessary that I should stop. Time would fail me to complete the analysis of the labors which have so fully occupied our sessions. I have been obliged to pass in silence many interesting facts, many important discussions. But if I have not been able to accomplish all my task, let the blame fall where it is due; by the aggrandizement of the field of research, by the multiplicity of their productions, my colleagues of the society have themselves rendered it impossible to condense in a few pages the results which have been accomplished. Thanks to their persevering efforts, the impulsion given to anthropological studies increases from day to day; the movement of our science becomes generalized, and is propagated in all parts of the world. It suffices to cast a glance on the first steps of the society to recognize with just satisfaction the extent of the route which has been traversed in less than eight years. What has been done in so short a space of time is a sure guarantee of what will be effected in the future.

DRILLING IN STONE WITHOUT METAL.

BY CHARLES RAU.

Some archæologists, among them Sir John Lubbock, incline to the opinion that the perforated stone axes and hammers which have been found in Europe are to be referred to the beginning of the bronze period. Many of those implements doubtless belong to the age of bronze; they have frequently been discovered in connection with bronze articles in ancient graves, and it is, moreover, well known that the manufacture and use of stone weapons and implements were everywhere continued for a long time after the introduction of bronze. These facts, however, furnish no evidence for ascribing pierced stone implements generally to the period in which the use of bronze was already known; in many cases, on the contrary, it may be inferred from the nature of their finding-places, as well as from the character of their perforations, that they belong to the stone age proper. In the illustrated catalogue of the collection in the Copenhagen museum, edited by Mr. J. J. A. Worsaae,* there are eleven representations of pierced stone implements attributed to the age of stone, and the foremost objects, figured to illustrate the bronze period, consist of seven perforated stone axes, distinguished by elegant shape and superior workmanship. Though I am not acquainted with the particular circumstances of the discovery of these implements, I have not the least doubt that the learned editor of the catalogue, in referring them respectively to the ages of stone and bronze, based his classification on tenable grounds.

A number of those lacustrian pile-works, which pertain exclusively to the stone age, have yielded stone axes and hammers, as, for instance, the station of Nussdorf, on the Lake of Ueberlingen, (an arm of the Lake of Constance) where no less than fifty have been found. Mr. Desor, on whom I rely for these facts, also mentions that in another lacustrian station of the stone age the articles in question are confined to the upper part of the "archæological stratum," that is, the stratum which contains relics of art. Pierced implements, therefore, would seem to belong, in those localities at least, to a later epoch of the stone age, and thus to mark a phase of progress in the gradual development of human skill during that period.†

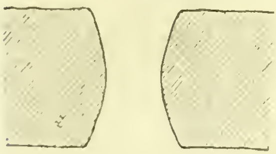
After a careful examination and comparison of the shaft-holes of European stone implements, I have arrived at the conclusion that two different methods, or, at least, two differently shaped drills were employed in making them. The more perfect perforations are of equal width, smooth and shining, and exhibit at certain distances circular striæ or furrows, which have the appearance of a succession of parallel rings. These perforations, I think, have been drilled with a hollow cylinder, perhaps a bronze tube, and I believe that the implements pierced in the manner described were mostly manufactured during the age of bronze. They are, moreover, very often remarkable for elegance of outline and high finish, indicating a state of art superior to that which is generally supposed to have existed in Europe during the period of stone. In other specimens the

* Worsaae, Nordiske Oldsager i det Kongelige Museum i Kjöbenhavn, 1859.

† Desor, Palafittes, or Lacustrian Constructions of the Lake of Neuchâtel; Smithsonian Report for 1865, p. 359, (note.)

shaft-holes are likewise more or less smooth, but destitute of the annular striæ, and sometimes narrower in the middle, in which cases, of course, a circular protuberance of corresponding size is formed. (Fig. 1.)

Fig. 1



These holes evidently were drilled from two sides, and the drilling implement was not a hollow cylinder, but a solid body, probably a wooden stick. Most of the axes and hammers provided with shaft-holes of this character are perhaps relics of the age of stone. It is hardly necessary to state that without the application of water and hard sand, drilling with either implement, hollow or solid, would have been impossible, and that the sand is to be considered as the chief agent in the process.

I had occasion to examine a number of European stone hatchets and hammers, which were in an unfinished state, the shaft-holes being only commenced or drilled half through, and the appearance of the latter perfectly corroborated my view concerning the different shapes of the drills used in making them; for some of these unfinished holes, and just such as belong to the striated class, have at the bottom a conical projection or a core, (Fig. 2,) which obviously resulted from the application of a hollow drilling implement; while others (Fig. 3) terminate in a rounded concave bottom, resembling exactly the cavity made by a wooden stick used as a drill.* I would not express this latter opinion so positively, if I could not rely on the results of experiments, having, in fact, succeeded in perforating a hard stone without any use of metal by means of a stick, in connection with sand and water. An account of the method employed by me, and of the results, I hope will be of interest to those archæologists who pay some attention to the minor details of their study.

Fig. 2.

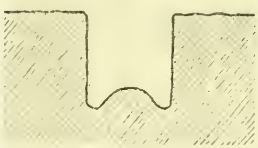


Fig. 3.

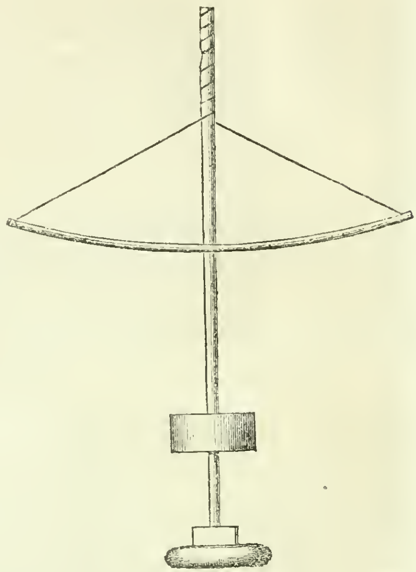
In the first place, I will give a description of my drilling implement, (Fig. 4,) which is, in fact, a pump-drill, the same apparatus that was used in former times by the Iroquois for the purpose of producing fire by friction.† It consists of a round wooden shaft, about four feet long and an inch in diameter at the upper end, but tapering a little towards the lower extremity, where it is provided with a heavy wooden disk, which acts as a fly-wheel. A bow or bent stick, three feet in length, with a long string attached to it, forms the second part of the apparatus. When used the string of the bow is passed through a notch cut in the top end of

* It afforded me some satisfaction to find my views confirmed, to a certain extent, in a work of Dr. Gustav Klemm. This author first alludes to Gutsmuths, who published an article in the "Morgenblatt," (1832, No. 253,) in which he tried to prove that a hollow cylinder of metal, used with emery in the manner of toothless stone saws, was the drilling implement of the ancients, basing his opinion upon the same facts which I already have stated, namely, the regularity of the holes, the core at their bottom, and the circular furrows. Klemm himself possessed in his collection a hollow bronze tube, five inches long, three-quarters of an inch in diameter, and covered all over with green rust, the *ærugo nobilis* of antiquaries. With such implements, he thought, the shaft-holes had generally been drilled, "but continued observation," he says, "convinced me that other methods also must have been employed. A stone axe of my collection, bored from two sides, exhibits conical cavities, the shape of which at once excludes the idea that a hollow cylinder was used in drilling them; the implement with which they were made, probably in a slow and painful way, evidently was a solid body." (*Klemm, Allgemeine Culturwissenschaft, Werkzeuge und Waffen, Leipzig*, 1854, *p.* 79.)

† Morgan, League of the Iroquois, Rochester, 1851, description and figure on page 381. Mr. Tylor gives likewise, on page 245 of his valuable "Researches into the Early History of Mankind," (London, 1865,) a drawing of the apparatus, but represents it as being moved with one hand only. In order to maintain the equilibrium of the shaft, it is necessary to apply both hands to the bow.

the stick and coiled around the stick, as indicated in the drawing. The bow is then seized with both hands and pressed downwards with a violent jerk. This motion uncoils the string and revolves the shaft towards the left, but by the action of the fly-wheel the string is coiled again around the shaft in a reverse manner, and the bow drawn up again. A second jerk at the bow causes the shaft to revolve towards the right, and by continuing this manipulation it is alternately swung around in opposite directions. The operator has it altogether in his power to work the apparatus slowly or rapidly, and, of course, with corresponding effect; but it requires some practice to use it in the proper manner.

Fig. 4.



The stone selected by me for the experiment is a flat, oval piece of diorite, of great hardness, not quite seven inches long, about five inches wide, and in the middle part one inch and three-eighths (a little over 3.5 centimeters) thick. I chose purposely that kind of stone, because it is the same of which the ancient inhabitants of Europe very often made their pierced implements. It is both hard and tough. These qualities were likewise appreciated by the North American aborigines, who used diorite extensively as the material for their tomahawks, large chisels, and pestles. The stone on which I operated is so hard that the point of a well-tempered penknife produces no scratch on its surface, but merely a metallic streak. The material used in drilling was a sharp quartz sand of middle grain, such as is employed in marble-yards; for a short time I also tried emery, but finding that it was not more effectual than sand, I continued to apply the latter. In order to render a beginning of the perforation possible, I tied a small square piece of board in which I had cut a round hole, corresponding to the lower diameter of the drilling-stick, with a string to the stone, just above the place where the bore was to be commenced. Without this contrivance, which I had to retain during the whole drilling process, the stick would constantly have slipped out of the hole. After these preparations I could begin the work, which was not very fatiguing, but tedious beyond description, taxing, in fact, my patience to the utmost degree. I never could endure the work for more than two hours in succession, and sometimes I laid the stone aside for weeks and months, until I had mustered sufficient energy to resume the labor. Thus it took two years before I succeeded in piercing the stone. I cannot exactly state how many hours I devoted to the work, but by measurement I obtained the result that two hours of constant drilling added, on an average, not more than the thickness of an ordinary lead-pencil line to the depth of the hole. The work would have advanced with incomparably greater speed, if I had selected a softer stone, serpentine, for instance, instead of the hard diorite; it was, however, my object to try the experiment on a hard mineral substance. Every five or six minutes the bore had to be cleaned by immersing the stone in water, the sand being by that time perfectly ground, and forming, in connection with the water and the particles of wood rubbed from the stick, a sort of paste, which was no longer serviceable for drilling. The quantity of sand introduced after every cleaning was about equal to the contents of a teaspoon. The shortening of the drilling-stick,

in consequence of wear, was considerable, and I had to replace it several times. The first was of tough ash wood; the others, which consisted of pine wood, proved to be just as efficient.

In the beginning of the work there appeared at the place of perforation a smooth, round spot. Becoming gradually larger, it formed a shallow basin, which finally, when the stone was drilled half through, assumed the appearance of a conical or funnel-shaped cavity. The deeper the drill penetrated into the stone the more difficult the work became, which induced me, after having drilled through half the thickness of the stone, to begin another bore at the opposite side. In due time it met the first exactly in the middle. It was originally my intention to drill a hole of about three-quarters of an inch in diameter, but I had not made sufficient allowance for the lateral friction of the sand, and hence it happened that the two conical cavities forming the perforation acquired, much against my wish, greater proportions than I expected, measuring, in fact, an inch and a quarter in their widest diameters. They would have become *narrower* as well as *more cylindrical*, if I had used a drill half as thick as that which served in the operation; but when I made this discovery the work was already too far advanced to be commenced again. Fig. 5 shows the present shape of the perforation. It is round and smooth, without exhibiting those circular furrows, which I have already ascribed to the action of a *hollow* drill. In order to complete the task in its fullest extent by producing a perfectly cylindrical hole, it would be necessary to remove, by continued drilling, the projecting rim between the dotted lines: a labor probably requiring as much time as that hitherto consumed. I cannot say whether I shall have sufficient leisure and patience to perform it; for the present I am satisfied with the fact of having, perhaps, practically illustrated one of the methods of drilling employed during the age of stone. Of course, it would be rashness on my part to assert that the apparatus used by me had also served as a drilling implement in ancient Europe; yet the possibility cannot be denied, for just as the Iroquois invented it for producing fire, the ancient nations of Europe may have constructed it for another purpose. Mr. Desor thinks it probable that the drilling was effected by means of very thin flakes of flint fixed around a stick, which was made to turn in such a way as to separate a portion of the stone, which, when the perforation was accomplished, would fall to the ground.* A drilling-stick of this description really may have served for perforating soft stones, but could not be successfully applied to hard materials. I operated myself with such a drill on diorite, and found the flint flakes invariably break off after the first revolutions. Yet, whatever may have been the means employed in drilling stone in the pre-historic ages of Europe, it is certain that the carefully fashioned and pierced implements must have possessed a very high value in the eyes of their manufacturers. Some indication of this fact is offered by the occurrence of the edged halves of axes broken across the shaft-hole, which had been rendered serviceable again by a second perforation. A specimen of this kind, of which the annexed reduced sketch (Fig. 6) presents the upper view, is preserved in the Peabody Museum at Cambridge, Massachusetts. It was found in northern Germany. The shaft-hole, which has been left in an unfinished state, evidently was formed by a solid drill. The material of this relic is variety of greenstone.

Fig. 5.

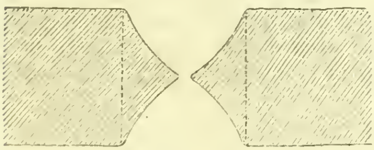
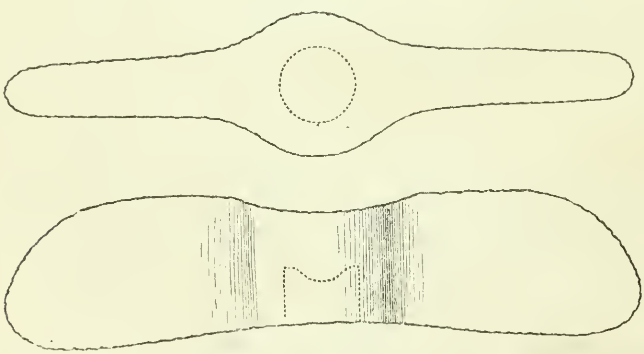


Fig. 6.

* Palafittes, &c., p. 359.

In North America the grooved tomahawk was, anterior to the occupation by Europeans, the prevailing implement of the axe-shape;* but pierced articles of this class also have been found, though not very frequently. Several are figured on page 218 of the "Ancient Monuments of the Mississippi Valley," by Squier and Davis. The material of most of those which I have seen is a rather soft stone of a greenish color, with darker veins or spots, capable of a fine polish. These perforated axes are mostly small, but very symmetrically shaped and highly finished. They were most probably worn on handles as badges of distinction by the superiors,† a supposition which gains strength from the fact that their material renders them unfit for real use. I know by experience that they occur from the Mississippi to the Atlantic coast. The peculiar stone of which they consist was also used for other objects, (the so-called gorgets, amulets, &c.,) and may have been an article of trade. The shaft-holes of these hatchet-like implements are exceedingly regular, and the annular striæ can often plainly be distinguished. They were doubtless produced by means of hollow drills, as will be seen hereafter. In addition to the perforated Indian axes just mentioned, there occur others, which are remarkable for being only pierced to a certain depth. It is true, I have not seen these latter very frequently, but in sufficient number to become convinced that the shaft-holes were purposely left in an unfinished condition. Their material is not the soft stone already referred to, but a harder substance, usually some kind of greenstone. They always present pretty much the same shape. The annexed half-size sketch (Fig. 7, upper and side view) shows the outline of one of these imple-

Fig. 7.



ments, which was found in western Massachusetts, and is now in the possession of Dr. Davis, of New York. The core at the bottom of the shaft-hole, which is indicated by dots, affords an indubitable proof that a hollow drill was employed. To render this implement serviceable for use, or even for show, a handle was driven as far as possible into the shaft-hole, and probably more firmly bound to

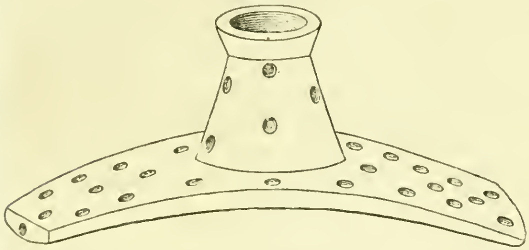
* Some ethnological writers, McCulloh and Schoolcraft, for instance, consider these stone axes as tools, and not as weapons; whereas it is most probable that they served both purposes, as occasion required. Men who were confined to the use of stone implements cannot be expected to have been very choice in their applications. A stone tomahawk, firmly attached to a withe, presented a very efficient battle-axe. Mr. Catlin gives, on plate 114 (vol. 2) of his well-known work, the portrait of *Mensónseah* (the Left Hand,) a Piankeshaw warrior, whom he represents with a helved stone tomahawk in his hand. Would this brave have allowed the artist to paint him thus accoutred, if he had not regarded his stone axe as a weapon? An Indian warrior, in his contempt for labor, certainly spurns the idea of being portrayed with a tool in his hand.

† Many of the perforated implements of Europe are supposed to have been destined for the same purpose.

the blade by ligatures. The depressions of the axe above and below the shaft-hole (observable in the side view) seem to have been destined for the reception of the fastening.

Yet, the manufactures of stone which evince the greatest skill of the former inhabitants of North America are by no means their pierced axes, but those remarkable pipes, often made of the hardest stones, that have been found in the so-called sacrificial mounds of the western States, but more especially in Ohio. These "mound pipes" usually represent bowl and tube in one piece, thus differing from the modern Indian pipe, which consists of a bowl and a long wooden stem, and bears a distant resemblance to the *chibouc* of the Turks. A great number of pipes of the above-mentioned antique shape were disentombed by Messrs. Squier and Davis during their survey of the ancient earth-works in the Mississippi valley, and are described and figured in their work already quoted by me, which forms the first volume of "Smithsonian Contributions to Knowledge."* The accompanying cut (Fig. 8) presents the outline of the mound-pipe in its simple or primitive form. The drawing is about half the size of the original, which was exhumed with many similar articles from a mound near Chillicothe, Ohio, and belonged formerly to the collection of Dr. Davis. It will be seen that the bowl rises from the middle of a flat and somewhat curved base, one side of which communicates by means of a narrow perforation, one-sixth of an inch (about four millimeters) in diameter, with the hollow of the bowl, and represents the tube, or rather the mouth-piece of the pipe, while the other unperforated end forms the handle by which the smoker held the implement and approached it to his mouth. Bowl and base are ornamented with small cup-shaped holes. This pipe consists of hard porphyry, and is wrought from a single piece, like all others of similar character. I have already stated that it may be considered as the simple or typical form of this class of implements. In the more elaborate specimens the bowl is formed in some instances in imitation of the human head, but generally of the body of an animal; and in the latter cases the peculiar characteristics of the species which have served as models, comprising mammals, birds, and amphibia, are frequently expressed with surprising fidelity; a modern artist, indeed, notwithstanding his far superior instruments, would find no little difficulty in reproducing the more finished of these objects, especially when carving them from porphyry, which was the kind of stone chiefly employed by the manufacturers. It must be borne in mind that the real use of metal was unknown to the ancient populations of North America. Implements and ornaments of copper, it is true, have been discovered, to a limited extent, in the mounds of the western States, and elsewhere, but the copper thus employed has not been obtained by the reduction from its ores; on the contrary, it is evident that the aborigines fashioned those articles from pieces of *native* copper, which they brought into the required shape by the simple process of hammering. They obtained the copper from the southern shore of Lake Superior, where extensive traces of their rude mining operations are still

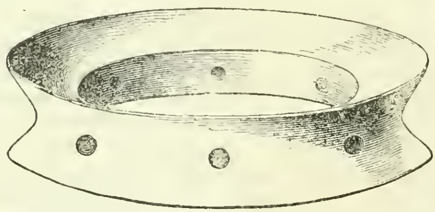
Fig. 8.



* The originals are now in the Blackmore Museum, at Salisbury, England, an institution of recent origin, to which Dr. Davis sold his excellent collection of Indian relics, mostly obtained during the survey to which I have alluded. Before the sale took place, I had constantly occasion to see the collection, and thus became familiar with the character of the specimens.

to be seen.* This hammered native copper is so soft that it can easily be cut with a knife, and therefore cannot have furnished the implements for working those hard mineral substances, which, indeed, successfully resist well-tempered steel. As a consequence, it must be presumed that the manufacturers of the pipes performed their work in the most tedious and painful manner, by rubbing the stone and grinding it with sharp sand and water, although this method leaves many details in the execution of their productions unexplained. In viewing, for example, their figures of birds, it is difficult to comprehend how they succeeded in representing the feathers, which are indicated by steady and boldly cut lines, straight and curved, in close imitation of nature.† The perforations and hollows of the mound-pipes are drilled with perfect accuracy, showing at once that the implement which produced them was not merely turned between the hands, but moved by an apparatus which coincided, in all probability, with the bow-drill still used by watchmakers and other artisans. The latter, it is well known, consists of a straight drill, which passes through the centre of a disk grooved at the periphery and revolves around two fixed points, one of them being formed by the bore. Motion is imparted by means of a bow, the string of which encircles the disk. It certainly would appear hasty to attribute to the aborigines of North America a knowledge of this implement, if it were not for the circumstance that there occur among the relics of the former population rings of stone and bone which are almost identical with the disks just mentioned, and most probably have served the same purpose. In fact, it is almost impossible to assign them any other destination. These rings are of various sizes, but similar in shape, being deeply grooved upon the outer edge, and pierced by eight equidistant small holes radiating from the centre.‡ Fig. 9 is a full-sized drawing of one which was discovered in a mound on the north fork of Paint creek, about six miles distant from Chillicothe, Ohio. The sketch, however, represents the object as perfect, whereas the original, formerly belonging to Dr. Davis, constitutes only one-half of the ring, which consists of a dark stone of medium hardness. The character of the rings encourages me to attempt the restoration of the an-

Fig. 9.



* Only the inhabitants of Mexico, and some countries in the southern portion of the American continent, understood the manufacture of bronze. It will hardly be necessary to add that iron was altogether unknown to the natives of America until Europeans taught them its use.

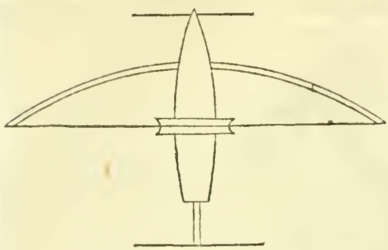
† The amount of labor bestowed upon the manufacture of these specimens must have been enormous, considering the time it is said to have required for fashioning articles of a much simpler character. According to Lafitau a North American Indian sometimes spent his lifetime in making a stone tomahawk, yet without entirely finishing it. *Lafitau, Mœurs des Sauvages Amériquains, Paris, 1724, vol. 2, p. 110.*

"Mr. Wallace has found that plain cylinders of imperfect rock crystal, four to eight inches long, and one inch in diameter, are made and perforated by very low tribes on the Rio Negro. They are not, as Humboldt seems to have supposed, the result of high mechanical skill, but merely of the most simple and savage processes, carried on with that utter disregard of time that lets the Indian spend a month in making an arrow. They are merely ground down into shape by rubbing, and the perforating of the cylinders, crosswise, or even lengthwise, is said to be done thus: A pointed flexible leaf-shoot of wild plantain is twirled with the hands against the hard stone, till, with the aid of fine sand and water, it bores into and through it, and this is said to take years to do. Such cylinders as the chiefs wear are said sometimes to take two men's lives to perforate. The stone is brought from a great distance up the river, and is very highly valued."—*Tylor, Researches, &c., p. 187.*

‡ Ancient Monuments of the Mississippi Valley, p. 224.

cient Indian bow-drill, which may have presented the shape indicated by Fig. 10.

Fig. 10.

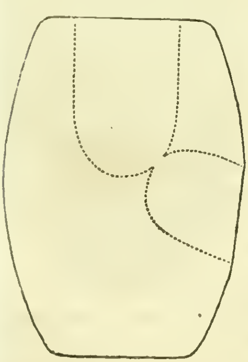


The ring, it seems, encircled a massive drill-holder, to which it was fastened by pegs driven through the holes on its periphery. Their purpose is thus fully explained.

May not an apparatus of similar construction also have been known in Europe during the bronze age, and even at an earlier period? In using the pump-drill, described and figured by me, constant oscillations of the shaft, tending to enlarge the bore, cannot be avoided; but they are altogether obviated when, as in Fig. 10, the upper end of the shaft or drill-holder revolves around a fixed point. And further, may not in Europe as well as in America the latter more perfect apparatus have superseded, in the course of time, the simpler contrivance with which I have experimented? This view will not appear strange, considering that man in all parts of the globe progressed slowly, and that every new development of ingenuity was based upon the results of former experience.

The greater number of drilled Indian implements which I had occasion to examine bore the unmistakable marks of having been perforated with hollow drills; yet I have also seen Indian performances in drilling indicating the application of solid implements. As an illustration I annex (Fig. 11, full size) the drawing of a pipe consisting of almost transparent rock crystal, which was taken from a mound near Bainbridge, Ross county, Ohio, and is now the property of Dr. Davis. Its shape, it will be observed, is that of a barrel somewhat narrowing at the bottom; it is regularly formed and highly polished. I left the drawing purposely without shading in order to indicate the two hollows, of which the upper one served as the receptacle for the smoking material, while that which meets it from the side was destined for the insertion of a stem. The terminations of the hollows are rounded, and consequently have been drilled with a solid implement.

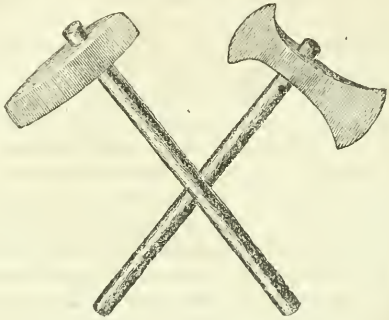
Fig. 11.



It is very likely that the *hollow* drills of the aborigines of North America were pieces of that hard and tough cane (*Arundinaria macrosperma*, Michaux,) which grows abundantly in the southern part of the United States, mostly along the banks of large rivers, and forms at present an article of trade, being used for pipe-stems and fishing-rods. This cane varies considerably in thickness; sometimes as thin as a straw, it assumes, when fully grown, the diametral proportions of a strong rifle-barrel, and even of larger cylindrical objects, in which cases it reaches the enormous height of 25 or 30 feet. A piece of this cane, from which the knotty joints have been cut, forms a regular hollow cylinder sufficiently strong to serve as a drill. I learned from Dr. Davis that many years ago a stone pipe with an unfinished hollow, partly filled with vegetable matter, was sent from Mississippi to the late Dr. Samuel G. Morton, of Philadelphia. When subjected to a microscopical examination the vegetable substance exhibited the fibrous structure of cane, and thus appeared to be the remnant of a drill broken off in the bore. It is, however, my intention to try the applicability of this cane by drilling experiments.

In conclusion, I will observe that the more finished stone articles of the former inhabitants of North America, and especially the pipes from the mounds, are

perhaps the best specimens of art left by any people to whom the use of metal was unknown, and that in examining the archæological collections of Europe, I have seen no objects produced under similar circumstances which display an equal degree of skill in the art of fashioning stone.



Ancient Stone Axes from North Germany.

A DEPOSIT OF AGRICULTURAL FLINT-IMPLEMENTS IN SOUTHERN ILLINOIS.

BY CHARLES RAU.

In an article published in the Smithsonian report for 1863 I gave, for the first time, an account and drawings of certain North American flint implements of large size and superior workmanship, which were evidently used by the aborigines for cultivating the soil and other digging purposes, and hence, according to their shape, classified by me as *shovels* and *hoes*. The annexed figures represent both kinds of implements. I described the shovels (Fig. 1) as oval plates of flint, flat on one side and slightly convex on the other, the outline being chipped into a sharp edge. The specimen here figured measures above a foot in length, a little more than five inches in its greatest breadth, and is about three-quarters of an inch thick in the middle. Others are narrower and not quite as heavy. The shape of the hoes is illustrated by Fig. 2. This specimen is seven and a half inches long, nearly six inches wide, and about half an inch thick in the middle. The rounded part forms a sharp edge. The material of which these implements are made is a peculiar kind of bluish, gray or brownish flint, of slightly conchoidal fracture, and capable of splitting into large flat fragments. I never succeeded in discovering this stone *in situ*. The agricultural implements of my collection were all found in St. Clair county in southern Illinois, with the exception of one shovel, which was dug up in 1861 in St. Louis, during the construction of earthworks for the protection of the city. Both shovels and hoes were, doubtless, attached to handles, those of the latter probably forming a right, or even an acute angle with the stone blade, which is always provided with two notches in the upper part to facilitate the fastening.*

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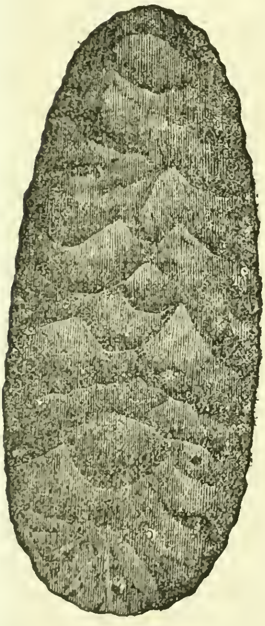

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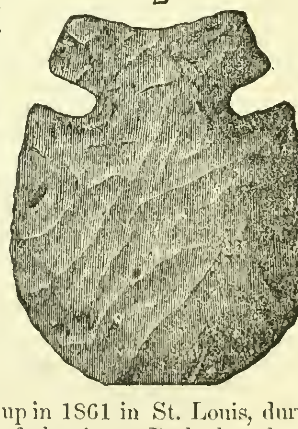


* I quoted a passage from *Du Pratz*, which is, perhaps, referable to the hoes. According to this author, the natives of Louisiana had invented a hoe, (pioche) with the aid of which they prepared the soil for the culture of maize. "These hoes," he says, "are shaped like a capital L; they cut with the edge of the lower part, which is entirely flat."—*Histoire de la Louisiane*, Paris, 1758. Vol. II, p. 176.

Plate XXI, in vol. II of *De Bry*, (Frankfort, 1591,) represents Florida Indians of both sexes engaged in field labor, the men using the hoe and the women sowing. The Latin text (by Le Moyne) accompanying the engraving states that the hoes are made of fish-bone, (*ligones e piscium ossibus*) and provided with wooden handles. The women sow beans and maize—"*feminæ fabas & milium sive Mayzum serunt.*"

Some of the shovels, like the specimen of which a drawing is given, measure a foot and more in length, and consequently are among the largest flint tools thus far discovered in any part of the world. Neither the rude hatchet-like and lanceolate implements found in the "drift" of France and England, associated with the osseous remains of the mammoth, the rhinoceros, and other animals of a bygone fauna, equal them in size; nor have, to my knowledge, the caves of the reindeer period in southern France and Belgium, once the resorts of savage hunting tribes, yielded any chipped flint articles of the same dimensions. Indeed, they are rivaled, as I think, only by the large flint celts of Scandinavia and northern Germany, which belong to a more advanced stage of the European stone age.

That the North American flint tools described by me were really used for digging can hardly be doubted. "If the shape of these implements," I stated in my account, "did not indicate their original use, the peculiar traces of wear which they exhibit would furnish almost conclusive evidence of the manner in which they have been employed; for that part with which the digging was done appears, notwithstanding the hardness of the material, perfectly smooth, as if glazed, and slightly striated in the direction in which the implement penetrated the ground." I further mentioned that this peculiar feature is common to all specimens of my collection as well as to the few which I have seen in the hands of others; and that they seem to be rather scarce, and merely confined to certain States bordering on the Mississippi river.

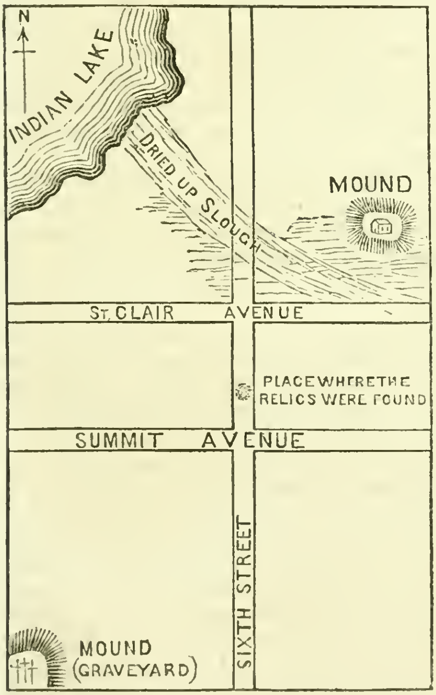
I was, therefore, much interested in the recent discovery of a large *deposit* of such implements at East St. Louis, (formerly Illinoistown,) in St. Clair county, Illinois, a place situated directly opposite the city of St. Louis, in the so-called "American Bottom," which forms a fertile plain extending for a considerable distance along the Mississippi shore in Illinois. This region, I must state, is very rich in Indian remains of various descriptions,* but particularly interesting on account of numerous artificial mounds, among which the celebrated truncated pyramid called Cahokia Mound, or Monk's Mound, is by far the most conspicuous, reminding the beholder of those gigantic structures in the valley of the Nile, which the rulers of Egypt have left to posterity as tokens of their power and their pride.

The particulars of the discovery to which I alluded were communicated to me by Dr. John J. R. Patrick, of Belleville, Illinois, a gentleman to whom I am greatly indebted for long-continued co-operation in my pursuits relative to the subject of American antiquities. As soon as Dr. Patrick heard of the discovery he hastened to East St. Louis, for the purpose of ascertaining on the spot all details concerning the occurrence of those flint tools; and in order to obtain still more minute information, he afterwards repeatedly revisited the place of discovery which is about 14 miles distant from Belleville, and can be reached after a short ride, the latter place being connected by railroad with East St. Louis. The removal of ground in extending a street disclosed the existence of the deposit, and Dr. Patrick derived all facts concerning its character from Mr. Sullivan, the contractor of the street work, who was present when the tools were exhumed, and therefore can be considered as a reliable authority. The results of my informant's inquiries, communicated in various letters addressed to me, are contained in the following account:

In the early part of December 1868, some laborers, while engaged in grading an extension of Sixth street in East St. Louis, came upon a deposit of Indian relics, consisting of flint tools, all of the hoe and shovel type, and of small fossil marine shells, partly pierced, and in quantity about equal to the contents of a bushel. Close by were found several boulders of flint and greenstone, weighing

* Some years ago I discovered near East St. Louis the traces of an Indian pottery, described in the Smithsonian report for 1866.

from 15 to 30 pounds each, and many fragments of flint. The soil in the immediate neighborhood is composed of black loam, overlying a stratum of a sandy character, and the deposit which occurred in the latter, was covered with from 18 to 24 inches of the black earth, bearing a luxuriant turf on its surface. According to the contractor's statement, the flint tools, the shells, and the boulders were deposited in three separate holes dug out in the sand, but not more than a foot apart from each other, and placed like the corners of a triangle. To use his language, the implements formed a "nest" by themselves, and so did the shells, and likewise the boulders. The flint tools, however, instead of being packed close together, like the shells and the boulders, were arranged with some regularity, overlapping each other or standing edgewise, and covering a circular space. The whole deposit did not extend more than seven or eight feet on either side. The contractor neglected to count the implements, but he thinks there were from 70 to 75 in all; some 50 hoes and about 20 shovels. No other stone articles, such as arrow and spear-heads, tomahawks, &c., had been deposited with the agricultural implements. The latter were soon taken away by persons from the place, attracted by the novelty of the occurrence, and it is to be regretted that many, if not most of them, have fallen into the hands of individuals who are unable to appreciate their value. But this is usually the case when discoveries of similar character are made. Dr. Patrick examined upwards of 20 of the flint implements, and found that none of them had been used, as they had not received the slightest polish on the cutting edge.



The place of discovery lies about a mile and a half, or still further, from the Mississippi, on elevated ground, and above ordinary high-water mark; but formerly, before the bed of the river was narrowed by the dike connecting the Illinois shore with Bloody Island, the distance cannot have been more than half a mile. The spot is situated nearly midway between two mounds, half a mile apart from each other. One of them was formerly used as a graveyard by the French of the neighborhood, and the other serves as the substructure for a dwelling-house. The accompanying plan (furnished by my correspondent) gives a view of the locality.

Several of the agricultural implements found at East St. Louis are now in my possession. Their material is a yellowish-brown variety of the flint to which I already referred. In shape they correspond with the tools of the same class previously described by me; most of the shovels, however, instead of having the end opposite the cutting part worked into a rounded edge, (like Fig. 1,) terminate in a more or less acute angle. The edges of all are chipped with the utmost regularity, and exhibit not the slightest wear, which proves that the implements were in a perfectly new condition when buried in the ground.

The fossil shells of marine origin are all small univalves, and belong almost entirely to the genus *melampus*. Of nearly 300 specimens sent to me by Dr. Patrick, 19 only represent other genera, namely, *columbella*, *marginella*. *conus*,

and *bulla*. All have a decayed and chalky appearance. They were probably obtained in the neighborhood, and obviously destined for ornamental purposes. This may be inferred from the fact that a number of the *melampus* shells are pierced with one hole in the lower part, (Fig. 3, natural size,) which was sufficient for stringing them, as the connecting thread could easily be passed through the natural aperture of the shell. On close examination I found that these shells had been reduced, by grinding, to greater thinness at the place of perforation, in order to facilitate the process of piercing.

3

The boulders, which formed a part of the deposit, were probably designated for the manufacture of implements. A piece of one of the boulders was sent to me for examination. It is a compact diorite, the material of which many ground articles of the North American Indians, such as tomahawks, chisels, pestles, &c., are made.

It would be useless to speculate on the antiquity of the objects thus accidentally discovered, for there are no indications for determining, even approximately, the period when they were buried. It is far easier to account for the motives which induced the owners of the tools and the other objects to dispose of them in the manner described. Their object was, in all probability, to *hide* them. Perhaps they left the place with a view to return and to take possession again of their concealed property, but were prevented from carrying out their intention. Or, they may have buried them in time of war, when they were killed, driven away, or led into captivity; and their "hidden treasure" lay undisturbed in the ground, perhaps for centuries, until the spade of the Irish laborer brought it to light again. There is no room whatever for the supposition that this deposit constituted one of those religious offerings by which the ancient inhabitants of the Mississippi valley believed they could gratify or propitiate the powers that ruled their destinies.

Similar deposits of flint articles have repeatedly been discovered in the United States,* and Messrs. Squier and Davis mention several instances of this kind in their work entitled "Ancient Monuments of the Mississippi Valley." The most extensive accumulation described by them occurred in one of the so-called sacrificial mounds of "Clark's Work," on North Fork of Paint creek, Ross county, Ohio. This mound contained, instead of the altar usually found in this class of earth-structures, an enormous number of flint disks standing on their edges, and arranged in two layers one above the other, at the bottom of the mound. The whole extent of these layers has not been ascertained; but an excavation six feet long and four broad disclosed upwards of six hundred of those disks, rudely blocked out of a superior kind of grayish striped flint. I had occasion to examine the specimens formerly in the collection of Dr. Davis, and have now a number of them in my own collection, which were sent to me from Ohio. They are either roundish, oval, or heart-shaped, and of various sizes, but on an average six inches long, four inches wide, and from three-quarters of an inch to an inch in thickness. They weigh not far from two pounds each. These flint disks are believed to have been buried as a religious offering, and the peculiar structure of the mound which inclosed them† rather favors this view. The disks, however, represent no finished implements, but merely flat pieces, rudely chipped around their edges, and destined, in all probability, to be wrought into more symmetrical forms. Thus it would rather seem that the contents of this mound constituted a kind of depot or magazine, from which supplies of flint could be drawn whenever there was a want of that material. Many of the disks under notice bear a striking resemblance to the flint "hatchets" discovered by Boucher de Perthes and Dr. Rigollot in the diluvial gravels of the valley of the Somme,

* Also in Europe. Deposits of flint arrow-heads, for instance, were found in Scotland.—*Logan*, "*The Scottish Gaël.*" Lond., 1831., Vol. I, p. 339.

† Ancient Monuments, &c., p. 158; drawings of the disks on p. 214.

in northern France.* The similarity in form, however, is the only analogy that can be claimed for the rude flint articles of both continents, considering that they occurred under totally different circumstances. The drift implements of Europe represent the most primitive attempts of man in the art of working stone, while the Ohio disks are the unfinished specimens of a race that constructed earthworks of amazing size, and was already highly skilled in the manufacture of weapons and tools of flint.

Yet I little doubt but that implements analogous in shape as well as in associations to those of the drift of Europe, will be found also in America; for indications of the high antiquity of man on the latter continent are not wanting, and the similarity in the early condition of the human race in various parts of the globe becomes more and more manifest by the results of archæological investigation.

Another occurrence of flint disks is recorded in a notice by Dr. Hoy, published in Lapham's "Antiquities of Wisconsin," one of the Smithsonian volumes: "Some workmen, in digging a ditch through a peat swamp near Racine, found a deposit of disks of hornstone, about 30 in number. They were immediately on the clay, at the bottom of the peat, about two and a half feet below the surface. Some of the disks were quite regular; they vary from half a pound to a pound in weight." A few of these are preserved in the collection of the Smithsonian Institution.

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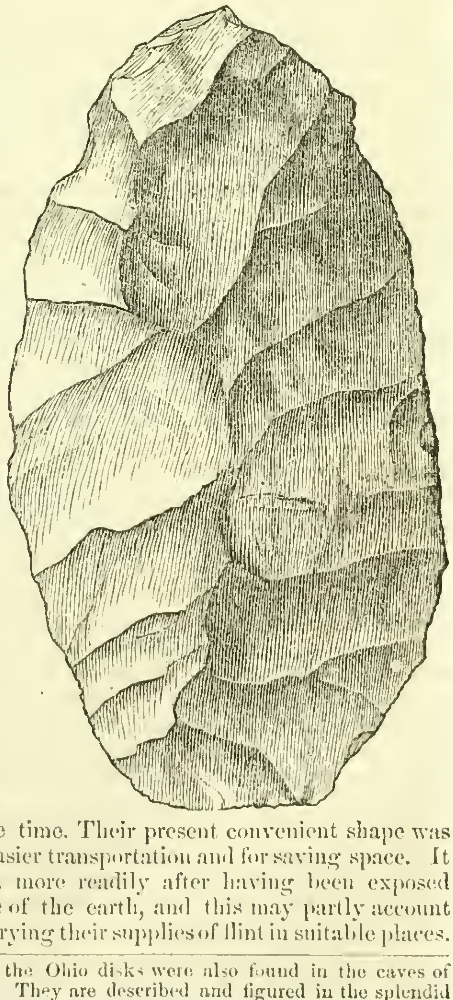

About 1860, while I lived in St. Louis, a quantity of rudely-shaped flint articles of similar character were discovered close together on the bank of the Mississippi, between St. Louis and Carondelet. It is probable that the falling down of a part of the bank had exposed them to sight. I could not ascertain their number, but saw about eight of them, of which I obtained three. They are nearly all of the same size, oval in shape, and consist of whitish flint. Fig. 4 represents one of my specimens in natural size. The original is seven-eighths of an inch thick in the middle part. It is evident that they are not implements in a state of completion, but roughly-edged fragments, which were destined to be made into arrow and spear-heads at some future time. Their present convenient shape was doubtless given them for the sake of easier transportation and for saving space. It is believed that flint can be chipped more readily after having been exposed for some time to the humid influence of the earth, and this may partly account for the practice of the aborigines of burying their supplies of flint in suitable places.

* Implements very similar in shape to the Ohio disks were also found in the caves of Dordogne, especially that of Le Moustier. They are described and figured in the splendid work by Lartet and Christy, entitled "Reliquiæ Aquitanicæ."

Returning to my former subject, I will observe that the occurrence of Indian flint tools which served for agricultural purposes is not more surprising than that of other stone implements indicating less peaceable pursuits; for it is known that many of the aboriginal tribes of North America raised maize and other nutritious plants before this continent was settled by Europeans.* The production of maize, indeed, must have been considerable. Mr. Gallatin has taken some pains to ascertain the area, east of the Rocky Mountains, and north of Mexico, over which cultivation extended. It was bounded on the east by the Atlantic; on the south by the Gulf of Mexico; on the west by the Mississippi, or, more properly, by the prairies. Towards the north the limits varied according to the climate; but near the Atlantic the northern boundary of agriculture lay in the region of the rivers Kennebec and Penobscot. North of the Great Lakes agriculture was only found among the Hurons and some kindred tribes. The Ojibways, on the south of Lake Superior, and their neighbors, the Menomonies, it appears, depended for vegetable food principally on the wild rice or wild oats, called *folle avoine* by the French.† The Iroquois tribes raised large quantities of Indian corn. In the year 1687, a corps under the command of the Marquis de Nonville made an invasion into the country of the Senecas, during which all their supplies of maize were either burned or otherwise spoiled, and the quantity thus destroyed is said to have amounted to 400,000 minots, or 1,200,000 bushels.‡ Though this estimate may be somewhat exaggerated, it nevertheless shows that these tribes paid much attention to the cultivation of maize.

The nations who inhabited the large territories formerly called Florida and Louisiana, probably obtained their food mostly from the vegetable kingdom. They cultivated chiefly maize, beans, peas, pumpkins, melons, and sweet potatoes. Maize, however, was their principal produce. In the accounts of De Soto's expedition, not only frequent allusion is made to the extensive maize fields of the natives, but it may also be gathered from these relations that the army of De Soto would have starved without the supplies of Indian corn obtained from the inhabitants. These people laid up stores of that useful cereal, and among other facts it is mentioned that one of De Soto's officers found in one house alone, five hundred measures of maize ground to meal, besides a large quantity in grain.§ But those southern tribes met by De Soto and his followers in the sixteenth century were the most advanced among the North American aborigines. No longer in the pure hunter state, but attached to the soil, they lived in large villages, consisting of dwellings more commodious than those of the ruder tribes, and paid generally more attention to the comforts of life than the latter.

Adair, who spent during the last century many years as a trader in the district under notice, mentions that the French of West Florida and the English colonists obtained from the Indians different sorts of beans and peas, with which they were before entirely unacquainted. They raised also a small kind of tobacco, differing from that in use among the French and English settlers. The women, he says, planted pumpkins and different species of melons in separate fields, at a considerable distance from the towns.‖ It is even probable that the former inhabitants cultivated fruit trees. Bartram, at least, found in Georgia and Alabama, on the sites of ancient Indian settlements, various kinds of trees, such as

* Some of the facts mentioned in the following remarks were already given in my previous article, published in the Smithsonian report for 1863; I repeat them here, for the sake of greater completeness, in connection with some additional details bearing upon the same subject. For descriptions of the remarkable "garden-beds" of Michigan, Wisconsin, and Indiana, which indicate an ancient cultivation, I must refer to Schoolcraft, Lapham, and others.

† *Gallatin*, Archæologia Americana, Vol. II, p. 149.

‡ Documentary History of New York, Vol. I, p. 238.

§ *Garcilasso de la Vega*, Conquête de la Floride. Leyden, 1731, Vol. I, p. 250.

‖ *Adair*, History of the American Indians. London, 1775, p. 408.

the persimmon, honey-locust, Chickasaw plum, mulberry, black walnut, and shell-barked hickory, which, he thinks, "were cultivated by the ancients on account of their fruit, as being wholesome and nourishing food."*

The Floridians, it is stated, employed at De Soto's time prisoners of war for working the fields, and in order to prevent their escape they partly maimed them by cutting the tendons of the leg above the heel or the instep.† It appears, however, that among most semi-agricultural tribes of North America field labor was imposed upon the women; while the men, when not engaged in hunting or war expeditions, abandoned themselves to that listless repose in which barbarians generally love to indulge.

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* *Bartram's* Travels. Dublin, 1793, p. 38.

† *Garcilasso de la Vega*, Conquête de la Floride, Vol. I, p. 286, and Vol. I, p. 389.

NOTICE OF THE BLACKMORE MUSEUM, SALISBURY, ENGLAND.

OPENED SEPTEMBER THE 5TH, 1867.

"*Time, which antiquates antiquities, and hath an art to make dust of all things, hath yet spared these minor monuments.*"—Sir THOMAS BROWNE.

The Blackmore Museum was founded at Salisbury, by Mr. William Blackmore, of Liverpool and London, in 1864. The public are admitted free upon days appointed by the committee of the Salisbury and South Wilts Museum, who have been constituted the governing body by Mr. Blackmore, subject, however, to the annual consent of the trustees, who are the founder, his brother, Dr. Blackmore, and his brother-in-law, Mr. E. T. Stevens.

GENERAL REMARKS.

The collection mainly consists of specimens belonging to the stone age of different countries.

It has been well remarked that "these implements of stone are to be regarded as indicating a grade of civilization, rather than any definite antiquity." One object of the founder of the Blackmore Museum accordingly has been, an attempt to illustrate the use and application of the rude weapons, implements, and ornaments of antiquity, by exhibiting, side by side with them, similar specimens in use among existing races of mankind.

The general result of this arrangement is, that a striking resemblance can be observed in the modes by which the simple wants of a common nature have been supplied among people widely severed from each other in point of time, no less than by geographical distribution.

Although this may be the first impression conveyed by a glance at the Blackmore and similar collections, more careful examination will show that special types (and in some instances special objects) occur in particular districts, and that frequently typical points of difference exist between *groups* of objects assigned to the same period and people, and obtained from spots almost close to each other. Thus in the case of two localities near Salisbury, there is a difference in type between *the group* of flint implements found in the drift-gravel at Bemerton and *the group* found in the drift-gravel at Milford Hill.

Taken as a whole, however, the flint implements of the drift have well-marked characteristics; nevertheless, in the Blackmore collection certain specimens from an American tumulus agree very closely with the usual drift types. Very drift-like implements have also been found in certain bone-caves, yet in each case the attention is chiefly arrested by the aberrant character of the specimens.

There is a class of flint implements known as "scrapers," one variety of which, usually large, thick-backed, and with a broad scraping edge, is found in the drift; it occurs again in cave deposits, as for instance in Le Moustier, Dordogne, and also with slight modification among ordinary surface specimens, although it ceases then to be a typical form. On the other hand, the type of "scraper" so abundant on the surface occurs, although rarely, in the drift.

Perhaps, therefore, we are scarcely in a position to state that any sharp line of demarcation absolutely severs the drift implements from those of the caves, or the implements of the caves from those of the surface. In palæontology the rare types of one period become the prevalent forms of another, in this respect presenting an analogy to the objects of the stone age. If we assume that the drift-folk "thought out" the form of their weapons and the mode of their manufacture in a manner entirely differing from what has been done by any other race of men, we are driven to the conclusion that there must have been also something wholly different in the drift-people themselves, or in the conditions under which they existed, for all later evidence tends to show that the workings of human minds and human hands in the stone age have produced very similar results in every quarter of the globe.

Be this as it may, the collection in the Blackmore Museum will remain what it is now, an assemblage of *facts*, however incorrectly we or other men may interpret them, and as such, the collection must ever retain its ethnological value, even should our present theories prove to be erroneous. The collection resembles so much sound material ready-quarried and fit for use, with which men can build—any errors in style, construction, or taste, must necessarily rest with the architect.

ARRANGEMENT.

The arrangement of the collection is far from being completed; as soon as possible, labels will be attached to the specimens and a list will be published, to be followed hereafter by an illustrated and descriptive catalogue.

CLASSIFICATION.

The classification adopted is as follows:

Archæolithic Period, (Lubbock.)

Fauna of "the Drift"—England.
Flint implements from "the Drift"—France.
" " " England.
Fauna of the Dordogne caves—France.
" caves in the Pyrenees—France.
" "Genista" caves—Gibraltar.
Flint implements and objects of human workmanship in bone, antler of reindeer, &c.—Dordogne caves, France.
" " " " " caves of the Pyrenees, France.
" " " " " "Genista caves," Gibraltar.

Neolithic Period, (Lubbock.)

Surface series, (rubbed stone group.)

Flint and stone implements, &c., from England, Ireland, France, Denmark, Italy, Arabia, East Indies, South Africa, America, &c.
Pfahlbauten series—Switzerland.

Surface series, (drilled stone group.)

Stone hatchets and other objects from America, Ireland, and Denmark.

Surface series, (carved and drilled stone group.)

Pipes and other objects from the mounds of Ohio—America.

Bronze series.

Bronze hatchets, spear heads, and personal ornaments, from England, Ireland, France, and America.

Iron series.

Iron swords and spear-heads—England, France.

Illustrative series.

Modern stone implements, chiefly in the original handles—New Zealand, Australia Islands of the Pacific, Esquimaux, &c.

Modern bone-armed weapons—British Guiana, New Guinea, Islands of the Pacific, Esquimaux, &c.
Modern iron-armed weapons—Africa, &c.
Personal ornaments, fishing-tackle, &c., made from seeds, shell, bone, horn, ivory—New Zealand, Islands of the Pacific, Esquimaux, &c.
Clubs, spears, paddles, &c.—New Zealand, Australia, New Guinea, Islands of the Pacific, British Guinea, Esquimaux, &c.

Fauna of the Drift.

The collection commences with remains of those (chiefly) extinct animals found in beds of sand, clay, or gravel, which cap hills, occur in patches on their sides, or constitute the sub-stratum of valleys in certain districts. For the purpose of this notice it may be sufficient to state that these beds are popularly known as "the Drift," and that the materials forming them have been derived from the wearing-down by water of the neighboring *up-stream* district. This wearing-down does not appear to have been entirely or even chiefly due to ordinary river action, but it was probably effected, in great degree, by torrents arising from the thawing of ice and snow, which accumulated under more rigorous conditions as to climate than is experienced in the same localities within the historic period.

In the series from our local drift (brick-earth) at Fisherton, attention is particularly called to some unique remains of one species of pouched marmot (*Spermophilus superciliosus.*) From a careful examination of several skeletons of these little rodents, it appears that the animals all perished during their winter's sleep—each being in the usual position assumed during hybernation. Possibly in this we see the effect of some unusually high flood. There are also exhibited remains of two species of lemming, *(Lemmus torquatus and L. Norvegicus,)* likewise unique in beds of this age. In the collection are portions of egg-shells from the brick-earth at Fisherton: these are unique.

ARCHÆOLITHIC PERIOD.

Flint implements from the Drift.

The interest felt in "the Drift" arises chiefly from the fact that in it are found implements made by the simple processes of flaking and chipping, which afford the first evidence we possess of man's existence upon the earth. The series of these implements in the Blackmore Museum is extensive and good, particularly so as regards those obtained from the drift of England, at Thetford, Icklingham, Bury St. Edmunds, and nearer Salisbury, at Hill Head, (near Fareham,) Bournemouth, Fordingbridge, and Lake, as well as those found close to this city, at Bemerton, and Milford Hill. Mr. Evans, F.R.S., of Hemel Hempsted; Mr. Flower, F.G.S., of Croydon; Mr. Wheaton, of Salisbury; and Mr. Toomer, also of this city, have contributed specimens. Many of the local flint implements collected by Mr. James Brown, and the important collection formed by Mr. Henry Prigg, jr., of Bury St. Edmunds, are also included in this series.

Cave series.

These objects consist of flint scrapers and implements—of harpoons carved from antlers of the reindeer—of bone needles—and of pieces of bone and horn upon which animals and other objects have been delineated. The specimens exhibited from the Dordogne caves (France) were chiefly presented by the trustees of the Christy Museum, London, and by M. Lartet, of Paris; many of the rarer specimens are represented by casts, the originals being in the museum at St. Germain. The specimens from the caves of the Pyrenees were obtained during excavations conducted by Dr. Garrigou, of Tarascon, at the expense of Mr. Blackmore; whilst the series from the caves at Gibraltar was presented by Colonel Henry Hope Crealock (Vienna) and Captain Brome, (Gibraltar.)

The resemblance between the objects from the French caves and those still made and used by the Esquimaux is very striking. Attention is directed to the cast of a portion of the tusk of a mammoth found in the rock-shelter of La Madelaine, Dordogne, upon which is traced in outline the animal (mammoth) itself. The specimen from which this cast has been taken was discovered in May, 1864, by M. Lartet, M. de Verneuil, and the late Dr. Falconer.

NEOLITHIC PERIOD.

Surface series, (rubbed stone group.)

Setting aside peculiarities in type between the earlier (archæolithic) flint implements already noticed, and the later, (neolithic,) now about to be considered, the difference in the mode of manufacture is remarkable. The former, without exception, owe their shape wholly to the simple processes of flaking and chipping; no instance of artificial rubbing occurs upon the drift implements; whilst among those belonging to the neolithic period a very large percentage, after having been chipped into form, have been rubbed and polished with more or less care. In the *rubbed* stone series are included those arrow-heads, scrapers, drills, wedges, hammers, and other objects, formed themselves for the most part by flaking and chipping only, but *contemporary* with the rubbed hatchets. In this section examples are shown from the neighborhood of Salisbury, from Weymouth, Icklingham, Yorkshire, and elsewhere in England, and from various parts of Ireland. Some nice specimens from Tan Hill, near Devizes, have been presented by Mr. Coombs, of Stapleford. Many of the Yorkshire specimens were presented by Mr. Monkman, of Malton. Mr. Evans, F.R.S., of Hemel Hempsted, has contributed a series from the shell-mounds (Kjökkenmöddings) of Denmark, and Mr. Flower, F.G.S., of Croydon, has given some from the shell-mounds of Herm, near Guernsey. There is also an interesting series of specimens from some (as is supposed) British pit-dwellings, near Salisbury, consisting of stone querns, flint and bone scrapers, bone-piercing tools, bone javelin-heads, clay pellets for slinging, clay spindle-whorls, pottery, and animal remains. For this collection the trustees are indebted to Mr. Adlam, of Salisbury, without whose valuable assistance the series could not have been formed.

Some interesting examples of human-worked flint and jasper, from the East Indies and South Africa, presented by Sir Charles Lyell, Bart., are exhibited, as are also some remarkable flint-cores from Scinde, presented by the Bedfordshire Architectural and Archæological Society, through Mr. Wyatt, F.G.S. In this section are some rude flint tools, obtained from the neighborhood of Rome, by the late Rev. Prebendary Chermside, in whom the Blackmore Museum has recently lost a most valuable friend. Flint knives from Arabia, presented by Mr. Franks, F.S.A., of the British Museum, and similar objects from various parts of France, Belgium, and Denmark, are exhibited.

Pfahlbauten series, (rubbed stone group.)

This portion of the collection is very illustrative; it has been formed through the extreme kindness of Admiral the Hon. E. A. J. Harris, C.B., her Majesty's minister at Berne, who has obtained the valuable assistance of such eminent Swiss archæologists as Dr. Keller, Professor Rütimeyer, Dr. Uhlmann, and the late M. Troyon. It is now well known that a pre-historic people drove wooden piles into the beds of the lakes of Switzerland and other countries, upon which a platform was placed, and upon this platform huts were erected.

In these huts these people dwelt, not for a month or two, but continuously, as appears to be proved by the presence of seeds of plants which ripen at various seasons of the year.

These lake-dwellers cultivated wheat and barley, spun and wove flax, made nets for fishing, while their tools (at the special stations represented in this col-

lection) were formed only from the bones and horns of animals, from stone, and from flint, which latter material they probably obtained from the south of France. Attention is called to a flake of flint in its original wooden handle, from the lake settlement at Robenhausen. Unfortunately, but a very small portion of the animal remains from the Swiss Pfahlbauten can be exhibited to the public from want of space, but the collection is peculiarly rich in this direction, through the friendly co-operation of Professor Rütimeyer, and every facility for access to it will be afforded to those interested in such a series.

American series, (rubbed stone group.)

This portion of the collection commences with a series of obsidian knives, arrow-heads, and drills, chiefly presented by the trustees of the Christy Museum, London. These, with some beads and ornaments of stone and shell, and a few stone hatchets, are relics of the ancient Mexicans, (Aztecs.)

The larger portion of the American series in the Blackmore Museum has been already fully illustrated and described by the Smithsonian Institution of Washington, United States, and is well known to scientific men as the "Squier and Davis" collection; it is now for the first time exhibited in Europe, having been purchased of Dr. Davis in 1864, when Mr. Blackmore was in New York.

From this collection are derived the very fine examples of stone arrow-heads and axes exhibited, as well as the specimens of worked bone, horn, and shell. Mr. Witt, F.G.S., of London, has contributed to this series.

Danish series, (rubbed stone group.)

This series consists of hatchets, tools, and weapons made from stone and flint, displaying great skill in the manufacture.

Belgian series, (rubbed stone group.)

The specimens forming this series have been presented by Mr. Evans, F.R.S., of Hemel Hempsted.

French series, (rubbed stone group.)

Some exquisite specimens are exhibited in this series.

American series, (carved stone group.)

These objects consist of heavy stone mauls, of pestles, and other food implements, among which are two specimens from Chiriqui, particularly worthy of attention, as are also some carved stone hatchets, and a carved stone dagger, all of Carib workmanship, and an ancient Egyptian stone ax-head.

Irish series, (drilled stone group.)

Spindle whorls, hatchets, &c.

Danish series, (drilled stone group.)

Spindle whorls, hatchets, &c.

American series, (drilled and carved stone group.)

This group contains some of the most interesting specimens in the collection; the greater part are extremely rare and some are unique. The celebrated carved stone smoking pipes, which have been figured in the first volume of the Smithsonian publications, (Washington,) are in this group, as are also the stone gorgets,

tubes, and drilled hatchets exhumed from the burial mounds of Ohio by Dr. Davis.

Illustrative series.

This series consists of hatchets, tools, arrows, spears, and other weapons; of fishing tackle, personal ornaments, &c., in use by modern savages, and calculated to throw light upon the mode of hafting and using the corresponding objects of antiquity.

Some clubs from New Zealand and some paddles from the Society Islands have been contributed by Mrs. Montgomery, of Nunton House, through the Salisbury and South Wilts Museum. This series has also been enriched by donations from Mr. Hamilton, M.P., and Mr. Marsh, M.P.

Bronze series.

The portion of this series now exhibited will probably be still further reduced, in order that the stone series may be extended. Among the bronze objects displayed is a good collection of the so-called "celts" from America, Ireland, France, and England, including the neighborhood of Salisbury. The specimens presented by the Viscount Folkestone, Mr. Benson, and Mr. Clench, to the Salisbury and South Wilts Museum, have been kindly lent by the committee of that museum, and are exhibited, as are also some interesting bronze daggers and other objects obtained by Mr. E. Dyke Poor, from a tumulus at Ablington, Wilts, and some bronze armillæ and a bronze torque, found in a tumulus at Lake by the late Rev. E. Duke, and presented to the Salisbury and South Wilts Museum by his son, the Rev. E. Duke, of Lake House.

Iron series.

The use of iron for arming weapons will, from want of space, be merely represented in the collection.

A few local specimens of the Anglo-Saxon period are exhibited. Some of these were presented by the late Mr. Swayne, of Bishopstone, and by Mr. F. Sidford, of the same place. The Salisbury and South Wilts Museum kindly contribute an Anglo-Saxon knife, presented by Mr. E. F. Mills, of Orcheston St. Mary.

Pottery.

Some Romano-British pottery, from the site of an old kiln near Fordingbridge, has been presented by Mr. Evans, F.R.S., of Hemel Hempsted, and some fine examples of Peruvian pottery have been contributed by Admiral Sir William Bowles, K.C.B., of London, through the Salisbury and South Wilts Museum.

PROGRAMME OF THE HOLLAND SOCIETY OF SCIENCES OF HARLEM, 1869.

The Holland Society of Sciences, held at Harlem, 15 May, 1869, its hundred and seventeenth annual session. The President-Director, Baron F. W. van Styrum, opened the sitting with an address in which he recalled the losses sustained by the society since its last general meeting; those, namely, of the director Baron G. F. Thoe Schwartzenberg at Hohenlansberg, of the native members G. Simons, H. C. Millies and J. van Lennep, and of the foreign members K. F. P. von Martius, at Munich, J. Plücker, at Bonn, H. von Meyer, at Frankfort-on-the-Maine, and C. S. M. Pouillet, at Paris. Finally, the nomination of M. G. Willink de Bennebroek, as a director of the society, was announced. Since the last annual meeting the society has published: *Archives Néerlandaises des Sciences exactes et naturelles,* parts 3, 4 and 5 of vol. iii, 1 and 2 of vol. iv.

In reference to a proposition submitted by MM. J. P. van Wickevoort Crommelin, D. de Haan, J. van der Hoeven, J. P. Delprat, R. van Rees, A. H. van der Boon Mesch, D. Lubach, and V. S. M. van der Willigen, and for the consideration of which a committee was appointed at the last general meeting, composed of the directors G. F. van Tets and J. P. van Wickevoort Crommelin, and of the members V. S. M. van der Willigen, G. de Vries, C. A. J. A. Oudemans, P. Harting and E. H. von Baumhauer, the society adopted the following as its decision:

1st. Besides the medals decreed for questions proposed for competition, the society ordains *two new medals*, each of the intrinsic value of 500 florins, one of them to bear the name and effigy of "HUYGHENS," the other those of "BOERHAAVE." 2d. These medals shall be alternately awarded, every two years, to the savant, whether Netherlander or foreigner, who by his researches shall, in the judgment of the society, have most contributed, during the last twenty years, to the progress of some definite branch of the physico-mathematical sciences or of the natural sciences. 3d. The Huyghens medal shall be assigned in 1870 to physics, in 1874 to chemistry, in 1878 to astronomy, in 1882 to meteorology, in 1886 to mathematics, (pure and applied.) The Boerhaave medal shall be assigned in 1872 to mineralogy and geology, in 1876 to botany, in 1880 to zoology, in 1884 to physiology, in 1888 to anthropology; and thereafter in the same recurrent succession. 4th. The preliminary judgment on the respective titles shall be referred to a committee named by the directors; of which committee the secretary of the society shall always be a member. 5th. The medal shall always be awarded by the general assembly, on the detailed and analytic report of the committee of judgment.

The following question having been offered for competition in 1865 and continued in 1867: "The society requests an exact description, with figures, of the skeleton and muscles of the *Sciurus vulgaris*, compared with what is known on this subject of the *Lemurides* and the *Chiromys*, in order that the place to be assigned to this last species in the natural classification may be determined with more certainty than has been heretofore possible;" a reply has been received through a memoir in the Dutch language, bearing the motto: *Beter is het te pogen zonder te slagen dan stil te zitten uit vrees voor nutteloose moeite.* (Better is it to endeavor without succeeding than to sit still from fear of profitless labor).

On the advice of the referees, the assembly awarded the gold medal to the author of the above memoir; which, upon the opening of the sealed note, was found to be the joint production of Dr. C. K. Hoffmann, adjunct physician at Meerenberg, and of M. H. Weijenbergh, jr., surgeon and accoucheur at Utrecht.

Of our own countrymen, the members elected at the session in question were MM. E. H. Beima, keeper of the museum of natural history at Leyden; R. P. A. Dozy, professor in the faculty of philosophy and letters at Leyden; J. F. W. Conrad, engineer-in-chief of the Waterstaat, at Middlebourg. Of foreigners, the following were at the same time elected members of the society: MM. L. A. J. Quetelet, from Brussels; W. Sartorius von Waltershausen, from Gottingen; A. W. Hofmann, from Berlin; J. D. Dana, from New Haven.

The president notified the assembly that the library, put in order and provided with a catalogue by the care of the secretary, is now at the disposal of the directors and members of the society.

The Society offers for competition the following questions, the answers to which must be addressed to it *before the 1st of January*, 1871:

I. The knowledge of the peat-bogs of the Netherlands, as well the higher as the lower, is yet far from being complete. There remain many researches to be made before we can determine with precision what are the plants of which they are composed; in particular, what are the ligneous substances found therein, and what the succession of the different vegetable species in the series of the beds of these peats, from the most ancient to those which still continue to be formed. The society desires to see this subject elucidated, and suggests consequently a thorough microscopic examination of the plants composing the Netherland peats.

II. The society requests an exact description of all the chemical or physical operations in which have been obtained, whether accidentally or by virtue of direct experiments, those chemical combinations which, by their chemical and physical characters, accord with the inorganic compounds existing in nature, under the form of minerals. The production of new artificial minerals is not asked for, but simply the critical appreciation of results already realized, with the exact indication of the works and memoirs in which the known artificial minerals have been described; in the classification of these products, conformity should be observed with some one of the mineralogical systems most extensively accepted.

III. The society considers it desirable that a description of the fossil flora of some of the coal deposits of Borneo should be given, and a comparison of that flora with those of other coal formations.

IV. The society desires a monograph of the substances called albuminous; this monograph should comprise an historical review of the numerous researches to which these substances have given rise and a critical appreciation of the opinions which at present maintain a footing in science with regard to this subject.

V. The society asks that the co-efficients of dilatation of different kinds of glass, especially of those which serve for the construction of thermometers, should be exactly determined, according to the method of M. Fizeau, between — 30 and + 500 degrees of the centigrade thermometer.

VI. Recent researches seem to confirm the opinion that the bodies called hydrates of carbon are polyatomic alcohols; the society invites new researches calculated to elucidate this important point.

VII. The determination of temperatures higher than 350 degrees of the centigrade thermometer still leaves, in all cases, much to be desired; the society will confer its gold medal for the construction of some very simple apparatus which shall give the temperatures up to at least 500 degrees of the centigrade scale.

VIII. The society solicits exact determinations regarding the variation of the indices of the refraction of water, for at least 12 points of the spectrum, on an extent of 50 degrees of the centigrade thermometer.

IX. It is known that the aurora borealis gives rise to telluric electrical currents which sometimes introduce considerable perturbations in the service of telegraphic lines. The society regards it as an object of interest that on telegraphic lines of great length determinations of the force of those currents should be made, to the effect, among others, of ascertaining to what point they extend towards the equator.

Questions to which an answer must be returned before 1st *of January*, 1873.

I. The society desires a complete critical review of the different phanerogamic floras of Europe, as well of those which have been published separately as of those which are to be found in the transactions of learned societies and in scientific journals. This review should be so arranged that the details concerning each country or province shall be mentioned in succession one after the other, according to the date of their publication. The work must be accompanied with critical observations relative to the greater or less value properly to be attributed to each flora, and to the opportunity afforded of deciding on the indications observed, or of proceeding to new researches in countries little known.

II. The society calls for a complete critical review of the different faunas of Europe, as well of those which have been published separately as of those which are extant in the collections of learned societies and in scientific journals. This review should be drawn up in the same form as regards arrangement and with the same conditions as those prescribed in the preceding question with reference to the different floras of Europe.

The following questions were last year submitted to competition by the society with a view to their being answered *before the* 1st *of January*, 1870:

I. Since the progressive decline and final suppression of the governmental culture of spices in the Molucca islands, it has become highly desirable that new lines of culture should be established in that fertile archipelago. The society consequently asks: (1.) A description of the present social condition of those islands, especially as regards the population and its aptitude for agricultural industry. (2.) Indications of the varieties of the soil, considered in relation to the culture proposed for eventual adoption. (3.) Statistical data on the results of the free cultivation of spices, as it is now practiced. (4.) A statement of the result of the experiment of cultivating cacao, undertaken by order of Governor-general Pahud and with the effective support of the government. (5.) A detailed specification of the vegetables, the culture of which would deserve to be tried among those whose products are suited for exportation.

II. It cannot be denied that spectral analysis, as at present conducted, tends to fall into excess and that its value is frequently exaggerated. Consequently, and in order to arrive at views at once more sound and of a more scientific character, it is required to make an equitable separation of the true from the false, to trace the limits within which the method may be legitimately employed and beyond which it ceases to be applicable, to submit to a sober critical appreciation the facts which it has brought to light, the discoveries which it promises, and those which we have a right to expect from it.

III. The galvanic current heats the metallic conductor which it traverses; by this, the resistance of the latter is augmented, and in this way the current reacts

on itself. On the other hand, it may be supposed that the intensity of the current further modifies the value of the resistance by virtue of an action which does not directly depend on the heating. It is desirable that, in one and teh other point of view, the influence exerted by the intensity of the current or the degree of the resistance, should be studied. Among the metals susceptible of being employed in this inquiry, mercury would seem to be one of those which offer the most advantages.

IV. The society solicits a criticism, as well as a repetition and extension of the experiments on the electrolysis of the melted haloid salts, (Faraday, *Experimental Researches*, vol. i, art. 538 *et seq.* and 978 *et seq.*,) together with an exposition of the considerations which are deducible therefrom on the nature of electrolysis.

The law of Faraday on electrolysis is extremely simple; but the question is far from being exhausted, and the *ensemble* of the phenomenon is as yet covered with a thick veil. Hence it is especially desirable to determine to what point the before-cited experiments are in opposition to that higher view, supported by a great number of facts, agreeably to which no true electrolysis can take place unless the action of the current is exerted on double salts or on combinations which are equivalent and analogous to them.

V. According to M. G. Ville, (see *Revue des Cours scientifiques*, 1868, No. 7, p. 103,) nitrogen in a free or elementary state is assimilated by certain plants, particularly by leguminous plants. The society wishes that this opinion should be submitted to a critical examination, and that its exactness or its falsity be established theoretically or experimentally, and preferably by both methods.

VI. In regard to the experiments of M. Graham, the society calls for new researches on the solutive power of melted metals for hydrogen, particularly with a view to deciding whether there exist definite combinations of metals with hydrogen.

VII. The society asks for an exact description, accompanied with figures, of the changes undergone by the organization of the Batrachians during their metamorphosis.

VIII. The assertion that metals become transparent at a temperature sufficiently elevated, requires to be confirmed or invalidated by experiments made on several different metals.

IX. The society wishes to have it experimentally determined whether the luminous power of the *Lampyris noctiluca et splendidula* (Linn.) should be attributed to the secretion of a particular matter, and if it be so, that the nature and composition of that matter be investigated.

X. There still exists much obscurity respecting the cause of the phosphorescence of the substances which bear the name of artificial phosphorus. The society invites a thorough investigation, to the end of deciding the question whether that phosphorescence should be attributed solely to a slow oxidation.

XI. Whilst, in meteorological observations, the pressure and temperature of the air, the direction and force of the wind are observed in a continuous manner, by means of registering instruments, we are always reduced, as far as the humidity of the air is concerned, to isolated observations made at certain hours of the day. The society desires the construction, whether upon new principles or such as have been already indicated, (see *Poggendorff's Annalen*, vol. 93, p. 343,) of a registering instrument for the determination of the humidity of the air, and solicits a communication of the results of observations made with such an instrument and continued during at least half a year.

XII. A memoir on the life of Koopman *(Mercator)* and of Ortels, *(Ortelius,)* and on the services which these two savants have rendered to geography, ethnology, and cartography, is regarded as a desideratum.

XIII. The society would wish that the biography of the Baron van Imhoff, and the history of his administration as governor-general of the Dutch Indies, should be written from documents not heretofore made use of.

XIV. The society invites an analysis of the life and a narrative of the voyages of Dutchmen who, in the 17th and 18th centuries, distinguished themselves as navigators or as authors of geographical discoveries.

XV. What has been done up to the present time, for the study of the languages of the populations subject to the domination of the Netherlands in countries beyond the sea, and what are the vacuities which it would be chiefly important to supply in this respect?

The Society recommend to competitors to omit in their replies all that has not an immediate relation to the question proposed. It hopes to find in everything submitted to it perspicuity united with brevity, and demonstrated propositions clearly distinguished from vague considerations and facts imperfectly established. It is further to be remembered that no memoir written by the hand of the author will be admitted to competition, and that, even were a medal awarded, its delivery would not take place if, in the meantime, the hand of the author should be recognized in the work accepted.

The notes attached to memoirs which fail to receive the prize shall be destroyed without being opened, unless it shall have been discovered that the memoir presented is but a copy extracted from printed works; in that case the name communicated will be divulged. Every member of the society shall have a right to take part in the competition, on condition that his memoir, as well as note, shall be signed with the letter L. The memoirs, written legibly, in *Dutch*, *French*, *Latin*, *English*, *Italian*, or *German*, (but not in German characters,) must be accompanied by a sealed note containing the name of the author, and be sent *free* to the secretary of the society, Professor E. H. von Baumhauer, at Harlem.

The prize offered for a satisfactory reply to each of the questions proposed, consists, at the choice of the author, either of a gold medal, bearing the usual stamp of the society, the name of the author and the date, or a sum of 150 florins; a supplementary premium of 150 florins may be added if the memoir be deemed worthy of it. The competitor who shall receive the prize will not be allowed to print his memoir, either separately or in another work, without the express authorization of the society.

PROGRAMME OF THE IMPERIAL ACADEMY OF SCIENCES, BELLES-LETTERS, AND ARTS OF BORDEAUX.

Questions submitted to competition for 1869 or following years:

I. *Literature.*—"Has a theatrical censorship been promotive of the morality of the art? What legislative measures would be suitable for protecting at once the liberty of authors and the respect for good morals?" Prize, a gold medal of 400 francs.

II. *History.*—First, "A history of the parliament of Bordeaux, from its origin to the end of the 16th century, with especial consideration of its influence as a political body and as a judicial body." Prize, a medal of gold of 500 francs. Second, "Origin of villanage and forced aids in Guienne, and the progress of their establishment." Prize, a gold medal of 200 francs. Third, "It would be interesting to have a particular history of several cities of our country, such as Saint Macaire, Cadillac, Sauveterre, Rions, Bazas, Lesparre, and some others." The Academy will award, in 1869 and 1870, a prize, which may amount to 500 francs, for a monograph of this kind in which personal matters and, as far as possible, the use of documents not hitherto explored shall be allied with competent qualifications of exactness and judgment. Fourth, "Among the institutions which have contributed to the honor and prosperity of the province of Guienne and the city of Bordeaux, the establishments of public instruction hold the first place; it is impossible to forget the services rendered by the college of Guienne, and, more recently, by the central school of the department." The Academy will award a gold medal of 300 francs to the best memoir which shall retrace the history of one of these establishments, or any analogous one; this thesis is proposed for 1869.

III. *Linguistics.*—It is desirable to have a general glossary of the Gascon tongue spoken in our department. In order to be complete it must comprise not only the synonyms and equivalents, but further and more especially the variations of words in the different dialects of the country. The compilation of such a work, however, can only be possible on the condition of having been preceded by the publication of special glossaries, embracing localities of more or less extent, but so restricted, nevertheless, that one single author may possess the dialect completely and exactly. The Academy solicits studious persons to direct their inquiries to this point before the use of the French language, becoming more and more general, shall have caused the last vestiges of these old idioms to disappear. Hence, the Academy proposes the following subject: "To compile, for the Gascon language, spoken in the department of the Gironde, a lexicon which, to an exact and sufficiently complete nomenclature of the words of a given locality, shall add the precise explanation of those words alike in their acceptation in common usage and in the idioms, adages, proverbs, agricultural by-words, Christmas carols and old songs in which they have been employed." Prize, a gold medal of 300 francs.

IV. *Physical sciences*—"A recapitulation of the consequences to which the ideas acquired, within a quarter of a century, on the equivalence of heat and mechanical work have led, whether in physics or in chemistry." Prize, a gold medal of 300 francs, which may be raised to 500 francs in case the production shall contain new facts. "A recapitulation and discussion of the facts acquired by science regarding the production and the consumption of forces in living beings." Prize, a gold medal of 500 francs.

V. *Natural sciences.*—"The construction of *aquariums* has enabled us to study the habits of a great number of animals. The basin of Arcachon having already been the scene of interesting investigations, the Academy desires that researches of this nature should be continued." To that end it proffers a prize of 500 francs.

Fauna of the Gironde.—The department of the Gironde possesses catalogues more or less complete of its vertebrate animals, its testaceous mollusks, coleoptera, lepidoptera, &c.; but this fauna, far advanced as it is, is wholly wanting in any collective review of the marine animals belonging to the inferior orders. Considering that in defect of rocky coasts our department includes at least a vast estuary (the basin of Arcachon) highly favorable to the study of a great number of these different organisms, the Academy would indicate the following as a desideratum: "The preparation of catalogues of the crustacea, annelidæ, radiata, &c., which are still deficient in the fauna of the department of the Gironde; to be accompanied by figures of new or little known species." Prize, a gold medal of 500 francs.

VI. *Physiology.*—The Academy having had the pleasure of crowning a meritorious memoir on a subject which it had proposed under this head, hopes to obtain a like gratifying result by presenting the following questions at once of scientific and practical interest and worthy of exciting the emulation of our savants: First. "A study of the anatomical and physiological relations which exist between the nervous cellules of the primitive fibers, sensitive and motive. The application of these researches to the study of reflex and sympathetic actions." Prize, a gold medal of 300 francs. Second, "Physiological and therapeutic effects of the *ingesta* which excite to labor and vigilance, which supply in part the place of aliments, and some of which are recognized as moderators of the vital combustion, such as alcohol, coffee, tea, maté, cocoa, &c." The prize will be a gold medal of 300 francs.

VII. *Fine arts.*—"State and tendency of religious architecture at the present epoch." Prize, a gold medal of 300 francs. "History of painting at Bordeaux." Prize, a medal, the value of which may extend to 500 francs.

VIII. *Poetry.*—The competition in poetry is subject to the conditions heretofore prescribed, and the choice of the subject remains optional with the author.

IX. *Biographical notices.*—As in previous years, the Academy invites biographical notices of the celebrated or useful men who have belonged either to the province of Guienne or to the department. "Life and works of Brascassat." Prize, a gold medal of 300 francs.

X. *Archeology.*—"Monograph of the church of Saint Michel of Bordeaux, with historic documents, plans and designs." Prize, a medal of 500 francs. "For the best memoir on the history of the church of Soulac, corroborated by plans, designs, and an indication of the original or printed documents consulted by the author." Prize, a gold medal of 300 francs. The Academy desiring to encourage archeological researches in the department of the Gironde, awards also *medals of encouragement* to the authors of the most important researches.

XI. *Hydrology.*—The question of artesian excavations has been *theoretically* treated for some isolated points of the vast basin of Aquitaine in the various publications and academic communications of MM. de Collegno, de Lamothe, Jacquot, and Raulin; it has been also *experimentally* solved by several successful trials made in the department. Many municipal administrations are, at this moment, asking for instructions on the chances of success which their localities offer for such enterprises. The Academy allying itself with this movement, proposes the following: "A discussion of the question of artesian borings in a *general* manner for Aquitaine, upon the data which geology furnishes with respect to the ground-slope of the aquitanic basin, its orographic characters and the levels of absorption of water presented by the different embanking rocks of its borders." Prize, a gold medal of 500 francs.

Conditions of competition.—The articles proposed for competition must fulfil the following conditions: Be written in French or Latin; be received at the secretariat of the Academy, *rue* Jean-Jacques Bel, before the 31st October, 1869 or 1870, as indicated in the programme; be free of postage; neither be signed by the author nor contain any indication by which he can be known; they shall bear an epigraph, which shall be repeated in a sealed note annexed to the article to which it belongs. This note, besides the epigraph, shall contain the name and address of the author, with the declaration that it has never been printed, offered for competition, or communicated to any academic society. An article proceeding from any author whose name shall be previously disclosed, will, from that circumstance alone, be excluded from competition. This condition is rigorous. The sealed notes will not be opened except in the case when an academic recompense shall have been obtained. From the observation of the above formalities are exempt, the productions of aspirants to medals of encouragement, and to prizes for obtaining which, local researches or the statement of experiments performed by the authors themselves shall be essential. Competition is open to both foreigners and natives, even to such of the latter as pertain to the Academy by the title of corresponding members.

Extract from the regulations of the Academy.—As soon as the Academy has rendered its decision, if there be prizes or honorable mention to be conferred, the president proceeds, in general assembly, to the opening of the sealed notes annexed to the prize essays. The notes pertaining to others are detached from the memoir, sealed by the president, and preserved by the archivist. The authors of the prize essays are immediately informed of the decision of the Academy, and those decisions are made public. The manuscripts and all the documentary papers of whatever nature, addressed to the Academy, remain in the archives after being marked with the initials and paraph of the president and secretary-general, and can in no case be removed. As the Academy, however, asserts no right of property over the papers, their authors may cause copies to be taken from the archives, after first proving that these productions belong to them. Independently of the prizes of which the subjects are named in the annual programme, the Academy bestows medals of encouragement on the authors who address to it works of real merit, and on persons who send to it documents on the different branches of science, letters and art. It may likewise award a prize to the corresponding member who shall have best merited it by the utility of his communications and the importance of the labors which he shall have submitted to it.

ROUX, *President.*
VALAT, *Secretary-General.*

A BRIEF ACCOUNT OF THE PROCESSES EMPLOYED IN THE ASSAY OF GOLD AND SILVER COINS AT THE MINT OF THE UNITED STATES.

FROM THE ANNUAL REPORT OF JAMES POLLOCK, DIRECTOR.

PRINCIPLES OF THE OPERATION.

According to law, the standard gold of the United States is so constituted that in 1,000 parts by weight 900 shall be of pure gold, and 100 of an alloy composed of copper and silver.

The process of assay requires that the copper and silver be both entirely removed from the gold; and to effect this, two separate operations are necessary.

The first is for the removal of the copper; and this is done by a method called *cupellation*, which is conducted in an assay furnace in a cupel composed of calcined bones. To the other metals, lead is added; this metal possesses the properties of oxidizing and vitrifying under the action of heat, of promoting at the same time the oxidation of the copper and other base metals, and of drawing with it into the pores of the cupel the whole of these metals, so as to separate entirely this part of the alloy, and to leave behind the gold and silver only.

The separation of the silver from the gold is effected by a process founded on the property possessed by nitric acid of dissolving silver without acting upon gold. But that the gold may not protect the silver from this action, sufficient silver must first be added to make it at least two-thirds of the mass. The process to be described is based upon the rule of *quartation*, in which the proportion of silver is three-fourths.

PROCESS OF ASSAY.

The reserved gold coins are placed in a black-lead crucible, and covered with borax to assist the fluxing and to prevent oxidation of the copper alloy. They are thus melted down and stirred; by which a complete mixture is effected, so that an assay piece may be taken from any part of the bar cast out. The piece taken for this purpose is rolled out for convenience of cutting. It is then taken to an assay balance (sensible to the ten-thousandth of a half gram or less,) and from it is weighed a half gram,, which is the normal assay weight for gold being about 7.7 grains troy. This weight is stamped 1000; and all the lesser weights, (afterwards brought into requisition,) are decimal divisions of this weight, down to one ten-thousandth part.

Silver is next weighed out for the quartation; and as the assay-piece, if standard, should contain 900 thousandths of gold, there must be three times this weight, or 2700 thousandths of silver; and this is accordingly the quantity used. It is true that there is already some silver in the alloy, but a little excess over the quantity required for the quartation does no injury to the process.

The lead used for the cupellation is kept prepared in thin sheets, cut into square pieces, which should each weigh about ten times as much as the gold under assay.

The lead is now rolled into the form of a hollow cone; and into this are introduced the assay gold and the quartation silver, when the lead is closed round them and pressed into a ball.

The furnace having been properly heated, and the cupels placed in it and

brought to the same temperature, the leaden ball, with its contents, is put into one of the cupels, the furnace closed, and the operation allowed to proceed until all agitation is ceased to be observed in the melted metal and its surface has become bright.

This is an indication that the whole of the base metals have been converted into oxides and absorbed by the cupel.

The cupellation being thus finished, the metal is allowed to cool slowly, and the disk or *button* which it forms is detached from the cupel.

The button is then flattened by a hammer; is annealed by bringing it to a red heat; is laminated by passing it between rollers; is again annealed; and is rolled loosely into a spiral or coil called a *cornet*. It is now ready for the process of quartation.

For this purpose, it is introduced into a matrass containing about $1\frac{1}{4}$ ounces of nitric acid at 22° of Baumé's hydrometer, and in this acid it is boiled for 10 minutes, as indicated by a sand-glass.

The acid is then poured off, and three-fourths of an ounce of stronger acid, at 32°, is substituted for it, in which the gold is boiled for 10 minutes.

This second acid is then also poured off, and another equal charge of acid of the same strength is introduced, in which the gold is kept for 10 minutes longer.

It is then presumed that the whole of the silver has been removed, and the gold is taken out, washed in pure water, and exposed, in a crucible, to a red heat, for the purpose of drying, strengthening, and annealing it.

Lastly, the cornet of fine gold thus formed is placed in the assay balance, and the number of thousandths which it weighs expresses the fineness of the gold assayed, in thousandths.

TEST ASSAY.

To test the accuracy of this process, the following method is employed:

A roll of gold, of absolute purity, which has been kept under the seal of the chairman of the assay commissioners, is opened in their presence, and from it is taken the weight of 900 parts. To this are added 75 of copper and 25 of silver, so as to form, with the gold, a weight of 1000 parts of the exact legal standard.

This is passed through the same process of assay as the other gold, and at the same time. After the assay is finished, it is evident that the pure gold remaining ought to weigh exactly 900. If, however, from any cause, it be found to differ from this weight, and therefore to require a correction, it is assumed that the same correction must be made in the other assays, and this is done accordingly.

ASSAY OF SILVER COINS.

PRINCIPLES OF THE OPERATION.

The standard silver of the United States is so constituted that of 1000 parts by weight 900 shall be of pure silver, and 100 of copper.

The process of assay requires that the exact proportion of silver in a given weight of the compound be ascertained, and this is done by a method called the *humid assay*, which may be explained as follows:

The silver and copper may both be entirely dissolved in nitric acid; and if to a solution thus made another of common salt in water be added, the silver will be precipitated in the form of a white powder, which is an insoluble chloride, while the copper will remain unaffected.

Now it has been ascertained that 100 parts by weight of pure salt will con-

vert into chloride of silver just 184.25 parts of pure silver; consequently the quantity of salt necessary to convert into chloride 1000 parts of silver is 542.74, as found by the proportion—

$$184.25 : 100 :: 1000 : 542.74.$$

A standard solution of salt is accordingly so prepared as that a given measure (the French decilitre) shall contain 542.74 thousandths of a gram of salt. The normal weight employed for silver assays is the gram, (equal to about 15.4 troy grains,) which is marked 1000, and has its subdivisions, in practical weighings, to the half or quarter thousandth.

Besides this standard solution, which effects the main precipitation of chloride of silver, there is a decimal solution, of one-tenth the proportion of salt, which it is expedient to use for the lesser and final precipitations.

In the mode of assay under consideration, it is necessary that the portion of alloyed silver used shall contain as nearly as may be 1000 parts of pure silver. The rigid standard requires that of 1000 parts by weight 900 shall be of pure silver; but the law allows a variation from this ratio, provided that it do not exceed three thousandths. The fineness may, therefore, be as low as 897, and as high as 903. In the practice of the assay, it is found most convenient to assume the lower extreme. Now, the weight of metal of the fineness 897, which would contain 1000 parts of silver, is 1114.83, as found by the proportion—

$$897 : 1000 :: 1000 : 1114.83.$$

The nearest integer to this number is employed, and the weight of metal taken for the assay is 1115.

PROCESS OF ASSAY.

The reserved silver coins are melted together in a black-lead crucible, with the addition of fine charcoal within the pot, to prevent oxidation, and to allow of dipping out. After stirring, a small portion of the fluid metal is poured quickly into water, producing a *granulation*, from which the portion for assay is taken. As this differs from the mode pursued with gold, it must be specially noted that in the case of silver alloyed with copper there is a separation, to a greater or less degree, between the two metals in the act of gradual solidification. Thus an ingot cooled in a mould, or any single coin cut out of such ingot, though really 900 thousandths fine on the average, will show such variations, according to the place of cutting, as might even exceed the limits allowed by law. This fact has been established by many experiments, both in this mint and the mint of Paris, since the enactment of our mint law; and it possesses the stubbornness of a law of chemistry. But the sudden chill produced by throwing the liquid metal into water yields a granulation of entirely homogeneous mixture, and it can be proved that the same fineness results, whether by assaying a single granule, or part of one, or a number together.

From this sample the weight of 1115 thousandths is taken, which is dissolved in a glass bottle with nitric acid.

Into this solution the large pipette-full of standard solution of salt is introduced, and it produces immediately a white precipitate, which is chloride of silver, and which contains, of the metallic silver, 1000 parts.

To make this chloride subside to the bottom of the vessel and leave the liquid clear, it is necessary that it be violently shaken in the bottle; and this is accordingly done by a mechanical arrangement, for the necessary time.

Unless the coins have chanced to be below the allowable limit of standard, the liquid will still contain silver in solution, and accordingly a portion of the decimal solution is introduced from the small pipette, capable of precipitating a

thousandth of silver, and a white cloud of chloride will show itself. More doses are added if the indications require it.

The liquid is again shaken and. cleared; and the process is thus repeated until the addition of the salt water shows only a faint trace of chloride below the upper surface of the liquid.

Let us suppose, for the sake of an example, that three measures of the decimal solution have been used with effect. This will show that the 1115 parts of the coin contained 1003 of pure silver; and thus the proportion of pure silver in the whole alloyed metal is ascertained.

TEST ASSAY.

For the foregoing process to be exact, it is necessary that the saline solution be of the true standard strength, or be such that the quantity of it, measured in the large pipette, shall be just sufficient to precipitate 1000 parts of silver. This cannot be assumed without proof, and a test assay is accordingly made as follows:

A roll of silver, known to be of absolute purity, is kept from year to year, in an envelope, under the seal of the chairman of the assay commissioners. This being opened in their presence, a portion of the silver is taken, and 1004 parts carefully weighed off and submitted to the process of assay described above. If the salt water used be of the exact standard, it is evident that as the solution in the larger pipette will precipitate 1000 parts of silver, four measures of the decimal solution will be required to precipitate the remaining four parts.

But as the normal or standard solution is affected, from day to day, by changes of temperature or other influences, the finishing decimal doses may be more or fewer; and the other assays are to be corrected by the proof-piece accordingly.

CALCULATION OF FINENESS.

By the assay thus corrected, the number of parts of silver contained in 1115 of the metal under trial is ascertained; and the fineness, in thousandths, is then found by the proportion: As 1115 is to the number of parts of fine silver, so is 1000 to the fineness of the alloyed silver, in thousandths.

Thus, if the assay show the presence $1005\frac{1}{2}$ parts of fine silver, the fineness of the alloyed silver will be 901.8 thousandths, as found by the proportion—

$$1115 : 1005.5 :: 1000 : 901.79.$$

It is on this principle that the following table is constructed. The numbers at the top and the fractions at the side correspond to the measures of the decimal solution used, corrected by the test assay. The numbers in the body of the table show the corresponding fineness of the assay-piece, of which the weight was 1115 parts:

	0	1	2	3	4	5	6
0	896.9	897.7	898.6	899.6	900.4	901.3	902.2
$\frac{1}{4}$	897.1	898.0	898.9	899.8	900.7	901.6	902.5
$\frac{1}{2}$	897.3	898.2	899.1	900.0	900.9	901.8	902.7
$\frac{3}{4}$	897.5	898.4	899.3	900.2	901.1	902.0	902.9

In the testing of single pieces it is to be expected that any gold coin, or a cut from any part thereof, will conform faithfully to the bounds prescribed by law. But the silver coins, in addition to the source of error already pointed out, (the manner of taking assay samples,) are somewhat liable to show too high a result, from several causes. At certain grades of alloy, and especially the standard of 900, the gradual cooling of ingots will draw the better metal to the interior, and the worst towards the exterior and the edges. Hence the fineness of pieces cut off the central part of the ingot is higher than the average fineness of the ingot. Again, in casting ingots from a melting-pot the exposure of the metal to the air during all the time of dipping out, and at the same time the increase of heat towards the bottom of the pot, unavoidably produces a progressive refining, so that the lower ingot is of a higher quality than the average of the whole melt; and, of course, a coin cut from it will be higher still. Yet with the precautions observed, our silver coins should very rarely exceed the superior limit assigned by law; and there is no good reason why they should fall below the legal limit, unless it be the taking of an unfair sample for assay.

A STATEMENT OF FOREIGN GOLD AND SILVER COINS, PREPARED BY THE DIRECTOR OF THE MINT, TO ACCOMPANY HIS ANNUAL REPORT, IN PURSUANCE OF THE ACT OF FEBRUARY 21, 1857.

EXPLANATORY REMARKS.

The first column embraces the names of the countries where the coins are issued; the second contains the names of the coin, only the principal denominations being given. The other sizes are proportional; and when this is not the case, the deviation is stated.

The third column expresses the weight of a single piece in fractions of the troy ounce carried to the thousandth, and in a few cases to the ten thousandth, of an ounce. The method is preferable to expressing the weight in grains for commercial purposes, and corresponds better with the terms of the mint. It may be readily transferred to weight in grains by the following rules: Remove the decimal point; from one-half deduct four per cent. of that half, and the remainder will be grains.

The fourth column expresses the fineness in thousandths, *i. e.* the number of parts of pure gold or silver in 1000 parts of the coin.

The fifth and sixth columns of the first table express the valuation of gold. In the fifth is shown the value as compared with the legal contents, or amount of fine gold in our coin. In the sixth is shown the value as paid in the mint, after the uniform deduction of one-half of one per cent. The former is the value for any other purposes than re-coinage, and especially for the purpose of comparison; the latter is the value in exchange for our coins at the mint.

For the silver there is no fixed legal valuation, the law providing for shifting the price according to the condition of demand and supply. The present price of standard silver is 122½ cents per ounce, at which rate the values in the fifth column of the second table are calculated. In a few cases, where the coins could not be procured, the data are *assumed* from the legal rates, and so stated.

Gold Coins.

Country.	Denominations.	Weight.	Fineness.	Value.	Val. after Deduct'n.
		Oz. Dec.	*Thous.*		
Australia	Pound of 1852	0.281	916.5	$5.32.4	$5.29.7
Australia	Sovereign of 1855-'60	0.256.5	916	4.85.7	4.83.3
Austria	Ducat	0.112	986	2.28.3	2.27
Austria	Sovereign	0.363	900	6.75.4	6.72
Austria	New Union Coin—assumed	0.357	900	6.64.2	6.60.9
Belgium	25 Francs	0.254	899	4.72	4.69.8
Bolivia	Doubloon	0.867	870	15.59.3	15.51.5
Brazil	20 Milreis	0.575	917.5	10.90.6	10.85.1
Central America	2 Escudos	0.209	853.5	3.68.8	3.66.9
Central America	4 Reals	0.027	875	0.48.8	0.48.6
Chili	Old Doubloon	0.867	870	15.59.3	15.51.5
Chili	10 Pesos	0.492	900	9.15.4	9.10.8
Denmark	10 Thaler	0.427	895	7.90	7.86.1
Ecuador	4 Escudos	0.433	844	7.55.5	7.51.7
England	Pound or Sovereign, new	0.256.7	916.5	4.86.3	4.83.9
England	Pound or Sovereign, ave'ge	0.256.2	916	4.85.1	4.82.7
France	20 Francs, new	0.207.5	899	3.85.8	3.83.9
France	20 Francs, average	0.207	899	3.84.7	3.82.8
Germany, north	10 Thaler	0.427	895	7.90	7.86.1
Germany, north	10 Thaler, Prussian	0.427	903	7.97.1	7.93.1
Germany, north	Krone (Crown)	0.357	900	6.64.2	6.60.9
Germany, south	Ducat	0.112	986	2.28.2	2.27.1
Greece	20 Drachms	0.185	900	3.44.2	3.42.5
Hindostan	Mohur	0.374	916	7.08.2	7.04.6
Italy	20 Lire	0.207	898	3.84.3	3.82.3
Japan	Old Cobang	0.362	568	4.44	4.41.8
Japan	Old Cobang	0.289	572	3.57.6	3.55.8
Mexico	Doubloon, average	0.867.5	866	15.53	15.45.2
Mexico	Doubloon, new	0.867.5	870.5	15.61.1	15.53.3
Mexico	20 Pesos (Max.)	1.086	875	19.64.3	19.54.5
Naples	6 Ducati, new	0.245	996	5.04.4	5.01.9
Netherlands	10 Guilders	0.215	899	3.99.7	3.97.6
New Granada	Old Doubloon, Bogata	0.868	870	15.61.1	15.53.3
New Granada	Old Doubloon, Popayan	0.867	858	15.37.8	15.30.1
New Granada	10 Pesos	0.525	891.5	9.67.5	9.62.7
Peru	Old Doubloon	0.867	868	15.55.7	15.47.9
Peru	20 Soles	1.055	898	19.21.3	19.11.7
Portugal	Gold Crown	0.308	912	5.80.7	5.77.8
Prussia	New Crown—assumed	0.357	900	6.64.2	6.60.9
Rome	2½ Scudi, new	0.140	900	2.60.5	2.59.2
Russia	5 Roubles	0.210	916	3.97.6	3.95.7
Spain	100 Reals	0.268	896	4.96.4	4.93.9
Spain	80 Reals	0.215	869.5	3.86.4	3.84.5
Sweden	Ducat	0.111	875	2.23.7	2.22.6
Tunis	25 Piastres	0.161	900	2.99.5	2.98.1
Turkey	100 Piastres	0.231	915	4.36.9	4.34.8
Tuscany	Seguin	0.112	999	2.31.3	2.30.1

Silver Coins.

Country.	Denominations.	Weight.	Fineness.	Value.
		Oz. Dec.	*Thous.*	
Austria	Old Rix Dollar	0.902	833	$1.02.3
Austria	Old Scudo	0.836	902	1.02.6
Austria	Florin before 1858	0.451	833	51.1
Austria	New Florin	0.397	900	48.6
Austria	New Union Dollar	0.596	900	73.1
Austria	Maria Theresa Dollar, 1780	0.895	838	1.02.1
Belgium	5 Francs	0.803	897	98
Bolivia	New Dollar	0.643	903.5	79.1
Bolivia	Half Dollar	0.432	667	39.2
Brazil	Double Milreis	0.820	918.5	1.02.5
Canada	20 Cents	0.150	925	18.9
Central America	Dollar	0.866	850	1.00.2
Chili	Old Dollar	0.864	908	1.06.8
Chili	New Dollar	9.801	900.5	98.2
China	Dollar, (English)—assumed	0.866	901	1.06.2
China	10 Cents	0.087	901	10.6
Denmark	2 Rigsdaler	0.927	877	1.10.7
England	Shilling, new	0.182.5	924.5	23
England	Shilling, average	0.178	925	22.4
France	5 Franc, average	0.800	900	98
France	2 Franc	0.320	835	36.4
Germany, north	Thaler before 1857	0.712	750	72.7
Germany, north	New Thaler	0.595	900	72.9
Germany, south	Florin before 1857	0.340	900	41.7
Germany, south	New Florin—assumed	0.340	900	41.7
Greece	5 Drachms	0.719	900	88.1
Hindostan	Rupee	0.374	916	46.6
Japan	Itzebu	0.279	991	37.6
Japan	New Itzebu	0.279	890	33.8
Mexico	Dollar, new	0.867.5	903	1.06.6
Mexico	Dollar, average	0.866	901	1.06.2
Mexico	Peso of Maximilian	0.861	902.5	1.05.5
Naples	Scudo	0.844	830	95.3
Netherlands	2½ Guilders	0.804	944	1.03.3
Norway	Specie Daler	0.927	877	1.10.7
New Granada	Dollar of 1857	0.803	896	98
Peru	Old Dollar	0.866	901	1.06.2
Peru	Dollar of 1858	0.766	909	94.8
Peru	Half Dollar 1835 and 1838	0.433	650	38.3
Peru	Sol	0.802	900	98.2
Prussia	Thaler before 1857	0.712	750	72.7
Prussia	New Thaler	0.595	900	72.9
Rome	Scudo	0.864	900	1.05.8
Russia	Rouble	0.667	875	79.4
Sardinia	5 Lire	0.800	900	98
Spain	New Pistareen	0.166	899	20.3
Sweden	Rix Dollar	0.092	750	1.11.5
Switzerland	2 Francs	0.323	899	39.5
Tunis	5 Piastres	0.511	898.5	62.5
Turkey	20 Piastres	0.770	830	87
Tuscany	Florin	0.220	925	27.6

LIST OF PUBLICATIONS OF THE SMITHSONIAN INSTITUTION TO JULY, 1869.

A. Journal of proceedings of the regents of the Smithsonian Institution, at the city of Washington, beginning on the first Monday of September, 1846. 1846. 8vo., pp. 32.

B. Report of the organization committee of the Smithsonian Institution, with the resolutions accompanying the same and adopted by the Board of Regents; also, the will of the testator, the act accepting the bequest, and the act organizing the Institution. Published by authority of the Board of Regents. 1847. 8vo., pp. 32.

C. Digest of the act of Congress establishing the Smithsonian Institution. Passed August 10, 1846. 8vo., pp. 8.

D. Address delivered on occasion of laying the corner stone of the Smithsonian Institution, May 1, 1847. By George M. Dallas, chancellor of the Institution. 1847. 8vo., pp. 8.

E. Smithson's bequest. Professor Henry's exposition, before the New Jersey Historical Society, at its meeting in Princeton, on Wednesday, September 27, by invitation from the executive committee. 1847. 8vo, pp. 8.

F. First report of the secretary of the Smithsonian Institution to the Board of Regents; giving a programme of organization, and an account of the operations during the year. Presented December 8, 1847. 1848. 8vo., pp. 48.

G. Report from the Board of Regents, submitted to Congress, of the operations, expenditures, and condition of the Smithsonian Institution. Read and ordered to be printed, March 3, 1847. Senate Doc. 211; 29th Congress, 2d Session. 1847. 8vo., pp. 38.

H. Second report of the Board of Regents of the Smithsonian Institution, to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution during the year 1847. January 6, 1848, ordered to be printed. 30th Congress, 1st Session. Senate Miscellaneous No. 23. 1848. 8vo., pp. 208.

I. Third annual report of the Board of Regents of the Smithsonian Institution to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution, during the year 1848. February 19, 1849, ordered to be printed. 30th Congress, 2d Session. H. R. Miscellaneous No. 48. 1849. 8vo., pp. 64.

J. Programme of organization of the Smithsonian Institution. [Presented in the first annual report of the secretary, and adopted by the Board of Regents, December 13, 1847.] 1847. 4to., pp. 4.

K. Correspondence relative to the acceptance for publication of the ethnological memoir of Messrs. Squier and Davis. 8vo., pp. 8.

L. [First] Report of the organization committee of the Smithsonian Institution. Reprinted from the National Intelligencer, December 8, 1846. 8vo., pp. 8.

M. Reports, Etc., of the Smithsonian Institution, exhibiting its plans, operations, and financial condition up to January 1, 1849. From the third annual report of the Board of Regents. Presented to Congress February 19, 1849. 1849. 8vo., pp. 72.

N. Officers and Regents of the Smithsonian Institution, with the act of Congress accepting the bequest, and the act incorporating said Institution. 1846, 8vo., pp. 14.

O. An act to establish the Smithsonian Institution. pp. 8.

P. Hints on public architecture, containing, among other illustrations, views and plans of the Smithsonian Institution: together with an appendix relative to building materials. Prepared, on behalf of the building committee of the Smithsonian Institution, by Robert Dale Owen, chairman of the committee. 1849. 4to., pp. 140, 15 plates and 99 woodcuts.

Q. Check list of periodical publications received in the reading-room of the Smithsonian Institution, for the year 1853. 1853. 4to., pp. 28.

REGULAR SERIES.

1. Ancient monuments of the Mississippi valley: comprising the results of extensive original surveys and explorations. By E. G. Squier, A. M., and E. H. Davis, M. D. Accepted for publication by the Smithsonian Institution, June, 1847. 4to., pp. 346, 48 plates and 207 woodcuts. (S. C. I.)

2. Smithsonian Contributions to Knowledge. Vol. I. 1848. 4to., pp. 346, 48 plates and 207 woodcuts.

CONTENTS.

(1.) Squier and Davis, Ancient monuments, Mississippi valley.

3. Researches relative to the planet Neptune. By Sears C. Walker, esq. [1850.] 4to., pp. 60. (S. C. II.)

4. Ephemeris of Neptune for the opposition of 1848. By Sears C. Walker, esq. 1849. 4to., pp. 8.

5. Appendix I. to vol. II. of the Smithsonian Contributions to Knowledge. [Ephemeris of the planet Neptune for the date of the Lalande observations of May 8 and 10, 1795, and for the opposition of 1846, '47, '48, and '49. By Sears C. Walker, esq. April, 1849.] 4to., pp. 32. (S. C. II.)

6. Appendix II. to vol. II. of the Smithsonian Contributions to Knowledge: containing an ephemeris of the planet Neptune for the year 1850. By Sears C. Walker, esq. [April, 1850.] 4to., pp. 10. (S. C. II.)

7. Appendix III. to vol. II. of the Smithsonian Contributions to Knowledge: Ephemeris of the planet Neptune for the year 1851. By Sears C. Walker, esq. [December, 1850.] 4to., pp. 10. (S. C. II.)

8. Occultations visible in the United States during the year 1848. [By John Downes.] 1848. 4to., pp. 12.

9. Occultations visible in the United States during the year 1849. Computed

under the direction and at the expense of the Smithsonian Institution. By John Downes. 1848. 4to., pp. 24.

10. Occultations visible in the United States during the year 1850. Computed by John Downes, at the expense of the fund appropriated by Congress for the establishment of a Nautical Almanac, and published by the Smithsonian Institution. 1849. 4to., pp. 26.

These three papers by Mr. Downes, Nos. 8, 9, 10, were not published in the series of Contributions.

11. Occultations visible in the United States during the year 1851. Computed by John Downes, at the expense of the fund appropriated by Congress for the establishment of a Nautical Almanac, and published by the Smithsonian Institution. [October,] 1850. 4to., pp. 26. (S. C. II.)

12. On the vocal sounds of Laura Bridgeman, the blind deaf mute at Boston; compared with the elements of phonetic language. By Francis Lieber. [1850.] 4to., pp. 32, and one plate. (S. C. II.)

13. Contributions to the physical geography of the United States. Part I. On the physical geography of the Mississippi valley, with suggestions for the improvement of the navigation of the Ohio and other rivers: By Charles Ellet, jr., civil engineer. Received September 17, 1849. [1850.] 4to., pp. 64, and 1 plate. (S. C. II.)

14. A Memoir on *Mosasaurus*, and the three allied new genera, *Holcodus*, *Conosaurus*, and *Amphorosteus*. By Robert W. Gibbes, M. D. Received November 15, 1849. [November, 1850.] 4to., pp. 14, and 3 plates. (S. C. II.)

15. Aboriginal monuments of the State of New York. Comprising the results of original surveys and explorations; with an illustrative appendix. By E. G. Squier, A. M. Accepted for publication, October 20, 1849. [1850.] 4to., pp. 188, 14 plates and 72 woodcuts. (S. C. II.)

16. The classification of insects from embryological data. By Professor Louis Agassiz. [Presented to the American Association for the advancement of science, at Cambridge, August, 1849.] Received March 6, 1850. [1850.] 4to., pp. 28, and one plate. (S. C. II.)

17. Memoir on the explosiveness of nitre, with a view to elucidate its agency in the tremendous explosion of July, 1845, in New York. By Robert Hare, M.D. Accepted for publication, October, 1849. [1850.] 4to., pp. 20. (S. C. II.)

18. Report on the history of the discovery of Neptune. By Benjamin Apthorp Gould, jr. 1850. 8vo., pp. 56.

19. Directions for meteorological observations, intended for the first class of observers. [By Arnold Guyot.] 1850. 8vo., pp. 40, and 9 woodcuts.

20. Microscopical examination of soundings, made by the United States Coast Survey off the Atlantic coast of the United States. By Professor J. W. Bailey. [January, 1851.] 4to., pp. 16, and 1 plate. (S. C. II.)

21. Fourth annual report of the Board of Regents of the Smithsonian Institution, to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution during the year 1849. 31st Con-

gress, 1st Session. Senate Miscellaneous No. 120. Read July 29, 1850. Ordered to be printed July 30, 1850. 8vo., pp. 272.

22. Plantæ Wrightianæ Texano-Neo-Mexicanæ. By Professor Asa Gray, M. D. Part I. Accepted for publication March, 1850. [March, 1852.] 4to., pp. 146, and 10 plates. (S. C. III.)

An account of a collection of plants made by Charles Wright in western Texas, New Mexico, and Sonora, in the years 1851 and 1852.

23. Microscopical observations made in South Carolina, Georgia, and Florida. By Professor J. W. Bailey. Accepted for publication December 1, 1850. [1851.] 4to., pp. 48, and 3 plates. (S. C. II.)

24. Appendix I. to vol. III. of the Smithsonian Contributions to Knowledge; containing an ephemeris of the planet Neptune for the year 1852. By Sears C. Walker, esq. [1853.] 4to., pp. 10. (S. C. III.)

25. Notices of public libraries in the United States of America. By Charles C. Jewett, librarian of the Smithsonian Institution. Printed by order of Congress as an appendix to the fourth annual report of the Board of Regents of the Smithsonian Institution. 1851. 8vo., pp. 210.

26. Smithsonian Contributions to Knowledge. Vol. II. 1851. 4to., pp. 464, and 24 plates.

CONTENTS.

(3.) Walker. Researches relative to Neptune.
(12.) Lieber. Vocal sounds of Laura Bridgeman.
(20.) Bailey. Microscopical soundings off Atlantic coast.
(13.) Ellet. Physical geography Mississippi valley and improvement of rivers.
(14.) Gibbes. Mosasaurus and three allied genera.
(16.) Agassiz. Classification of insects from embryological data.
(17.) Hare. Explosiveness of nitre.
(23.) Bailey. Microscopical observations in South Carolina, Georgia, and Florida.
(15.) Squier. Aboriginal monuments of state of New York.
(4.) Walker. Ephemeris of Neptune for 1848.
(6.) Walker. Ephemeris of Neptune for 1850.
(7.) Walker. Ephemeris of Neptune for 1851.
(11.) Downes. Occultations visible in the United States in 1851.

27. On recent improvements in the chemical arts. By Professor James C. Booth and Campbell Morfit. 1852. 8vo., pp. 216. (M. C. II.)

28. Fifth annual report of the Board of Regents of the Smithsonian Institution, to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution, during the year 1850. Special session, March, 1851. Senate Miscellaneous No. 1. Read March 1, 1851. Ordered to be printed March 7. 1851. 8vo., pp. 326.

29. Occultations visible in the United States during the year 1852. Computed by John Downes, at the expense of the fund appropriated by Congress for the establishment of a Nautical Almanac, and published by the Smithsonian Institution. 1851. 4to., pp. 34. (S. C. III.)

30. Contributions to the natural history of the fresh water fishes of North America. By Charles Girard. I—A monograph of the cottoids. Accepted

for publication December, 1850. [December, 1851.] 4to., pp. 80, and 3 plates. (S. C. III.)

31. A Collection of meteorological tables, with other tables useful in practical meteorology. Prepared by order of the Smithsonian Institution. By Arnold Guyot. 1852. 8vo., pp. 212.

32. Nereis Boreali-Americana: or, contributions to a history of the marine algæ of North America. Part I.—Melanospermeæ. By Professor William Henry Harvey. Accepted for publication July, 1851. [January, 1852.] 4to., pp. 152, and 12 colored plates. (S. C. III.)

33. The Law of deposit of the flood tide: its dynamical action and office. By Charles Henry Davis, Lieutenant U. S. Navy. Accepted for publication December, 1851. [1852.] 4to., pp. 14. (S. C. III.)

34. Directions for collecting, preserving, and transporting specimens of natural history. Prepared for the use of the Smithsonian Institution. Third edition. March 1859. 8vo., pp. 40., 6 woodcuts. (M. C. II.)

35. Observations on terrestrial magnetism. By Professor John Locke, Accepted for publication July, 1851. [April, 1852.] 4to., pp. 30. (S. C. III.)

36. Researches on electrical rheometry. By Professor A. Secchi. Accepted for publication September, 1850. [May, 1852.] 4to., pp. 60, and 3 plates. (S. C. III.)

37. Descriptions of ancient works in Ohio. By Charles Whittlesey. Accepted for publication May, 1850. [1851.] 4to., pp. 20, and 7 plates. (S. C. III.)

38. Smithsonian Contributions to Knowledge. Vol. III. 1852. 4to., pp. 564, and 35 plates.

CONTENTS.

(35.) Locke. Terrestrial magnetism.
(36.) Secchi. Electrical rheometry.
(30.) Girard. Monograph of the cottoids.
(32.) Harvey. Marine algæ of North America. Part I.—Melanospermeæ.
(22.) Gray. Plantæ Wrightianæ Texano-Neo-Mexicanæ. Part I.
(33.) Davis. Law of deposit of the flood tide.
(37.) Whittlesey. Descriptions of ancient works in Ohio.
(24.) Walker. Ephemeris of the planet Neptune for 1852.
(29.) Downes. Occultations visible in United States during 1852.

39. Smithsonian Contributions to Knowledge. Vol. IV. 1852. 4to, pp. 426.

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(40.) Riggs. Dakota Grammar and Dictionary.

40. Grammar and dictionary of the Dakota language. Collected by the members of the Dakota mission. Edited by Rev. S. R. Riggs, A. M., Missionary of the American Board of Commissioners for Foreign Missions, under the patronage of the Historical Society of Minnesota. Accepted for publication December, 1851. [1852.] 4to., pp. 414. (S. C. IV.)

A small edition of the grammar only was printed separately.

41. Memoir on the extinct species of American ox. By Joseph Leidy, M. D. Accepted for publication September, 1852. [December, 1852.] 4to., pp. 20, and 5 plates. (S. C. v.)

42. Plantæ Wrightianæ Texano-Neo-Mexicanæ. Part II. By Professor Asa Gray. Accepted for publication October, 1852. [February, 1853.] 4to., pp. 120, and 4 plates. (S. C. v.)

43. Nereis Boreali-Americana: or, contributions to a history of the marine algæ of North America. Part II.—Rhodospermeæ. By Professor W. H. Harvey. [March, 1853.] 4to., pp. 262, and 24 plates, colored. (S. C. v.)

44. A flora and fauna within living animals. By Joseph Leidy, M. D. Accepted for publication December, 1851. [April, 1853.] 4to., pp. 68, and 10 plates. (S. C. v.)

45. Anatomy of the nervous system of *Rana pipiens.* By Jeffries Wyman, M. D. Accepted for publication May, 1852. [March, 1853.] 4to., pp. 52, 4 woodcuts and 2 plates. (S. C. v.)

46. Plantæ Frémontianæ; or, descriptions of plants collected by Colonel J. C. Frémont in California. By John Torrey, F. L. S. Accepted for publication September, 1850. [1853.] 4to., pp. 24, and 10 plates. (S. C. VI.)

47. On the construction of catalogues of libraries, and their publication by means of separate, stereotyped titles. With rules and examples. By Charles C. Jewett, Librarian of the Smithsonian Institution. 1852. 8vo., pp. 78. Second edition, 1853. 8vo., pp. 108.

48. Bibliographia Americana Historico-Naturalis. A. D. 1851. Auctore Carolo Girard. December, 1852. 8vo., pp. 68.

49. Catalogue of north American reptiles in the museum of the Smithsonian Institution. Part I.—Serpents. By S. F. Baird and C. Girard. January, 1853. 8vo., pp. 188. (M. C. II.)

50. Synopsis of the marine invertebrata of Grand Manan: or the region about the mouth of the Bay of Fundy, New Brunswick. By William Stimpson. Accepted for publication January, 1853. [March, 1853.] 4to., pp. 68, and 3 plates. (S. C. VI.)

51. Sixth annual report of the Board of Regents of the Smithsonian Institution, to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution during the year 1851, and the proceedings of the Board of Regents up to date. [32d Congress, 1st session, Senate Mis. No. 108. 1852. 8vo., pp. 104.

52. Winds of the northern hemisphere. By Professor James H. Coffin, A. M. Accepted for publication November, 1850. Revised, November, 1852. [November, 1853.] 4to., pp. 200, 13 plates, and 6 woodcuts. (S. C. VI.)

53. Portraits of north American Indians, with sketches of scenery, Etc., Painted by J. M. Stanley. Deposited with the Smithsonian Institution. [December, 1852.] 8vo., pp. 76. (M. C. II.)

54. Occulations of planets and stars by the moon, during the year 1853. Computed by John Downes, at the expense of the fund appropriated by Con-

gress for the establishment of a Nautical Almanac, and published by the Smithsonian Institution. 1853. 4to., pp. 36. (S. C. VI.)

55. Smithsonian Contributions to Knowledge. Vol. V. 1853. 4to., pp. 538, and 45 plates.

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(44.) Leidy. Flora and fauna within living animals.
(41.) Leidy. Extinct species of American ox.
(45.) Wyman. Anatomy of the nervous system of Rana pipiens.
(43.) Harvey. Marine algæ of North America. Part II.—Rhodospermeæ.
(42.) Gray. Plantæ Wrightianæ. Part II.

56. Smithsonian Contributions to Knowledge. Vol. VI. 1854. 4to., pp. 476, and 53 plates.

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(46.) Torrey. Plantæ Frémontianæ.
(60.) Torrey. Batis maritima.
(61.) Torrey. Darlingtonia californica.
(50.) Stimpson. Marine invertebrata of Grand Manan.
(52.) Coffin. Winds of the northern hemisphere.
(58.) Leidy. Ancient fauna of Nebraska.
(54.) Downes. Occultations during the year 1853.

57. Seventh annual report of the Board of Regents of the Smithsonian Institution, to the Senate and House of Representatives, showing the operations, expenditures, and condition of the Institution during the year 1852, and the proceedings of the Board of Regents up to date. [32d Congress, 2d session, Senate Mis. No. 53.] 1853. 8vo., pp. 96.

58. The ancient fauna of Nebraska: or, a description of remains of extinct mammalia and chelonia, from the Mauvaises Terres of Nebraska. By Professor Joseph Leidy, M. D. Accepted for publication December, 1852. [June, 1853.] 4to., pp. 126, 3 woodcuts, and 25 plates. (S. C. VI.)

59. Account of a tornado near New Harmony, Indiana, April 30, 1852, with a map of the track, &c. By John Chappelsmith. Accepted for publication December, 1853. [April, 1855.] 4to., pp. 12, one map, one plate, and two woodcuts. (S. C. VII.)

60. Observations on the *Batis maritima* of Linnæus. By John Torrey, F. L. S. Accepted for publication September, 1850. [April, 1853.] 4to., pp. 8, and 1 plate. (S. C. VI.)

61. On the *Darlingtonia californica;* a new pitcher-plant from northern California. By John Torrey, F. L. S. Accepted for publication September, 1850. [April, 1853.] 4to., pp. 8, and 1 plate. (S. C. VI.)

62. Catalogue of the described coleoptera of the United States. By Friedrich Ernst Melsheimer, M. D. Revised by S. S. Haldeman and J. L. Le Conte. July, 1853. 8vo., pp. 190.

63. Notes on new species and localities of microscopical organisms. By Professor J. W. Bailey, M. D. Accepted for publication November, 1853 [February 1854.] 4to., pp. 16, 4 woodcuts, and 1 plate. (S. C. VII.)

64. List of foreign institutions in correspondence with the Smithsonian Institution. 1856. 8vo., pp. 16.

65. Registry of periodical phenomena. Folio, pp. 4.

66. The annular eclipse of May 26, 1854. Published under the authority of Hon. James C. Dobbin, Secretary of the Navy, by the Smithsonian Institution and Nautical Almanac. 1854. 8vo., pp. 14, and 1 map.

67. Eighth annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution up to January 1, 1854, and the proceedings of the Board up to July 8, 1854 [33d Congress, 1st session, House of Representatives, Mis. Doc. No. 97.] 1854. 8vo., pp. 310.

This is the first of the series of annual reports published by Congress as a bound volume, and it contains among other articles the first, second, third, fourth, fifth, sixth, and seventh reports of Professor Henry, the secretary; reports of committee on distribution of Smithsonian income; will of Smithson; notices of life of Smithson, and list of his scientific papers; Acts of Congress accepting the bequest, and establishing the Institution.

68. Vocabulary of the jargon or trade language of Oregon. [By Dr. B. Rush Mitchell, United States Navy, with additions by Professor W. W. Turner. April, 1853.] 8vo., pp. 22.

69. List of domestic institutions in correspondence with the Smithsonian Institution. 1853. 8vo., pp. 16.

70. The antiquities of Wisconsin, as surveyed and described. By I. A. Lapham, civil engineer, Etc., on behalf of the American Antiquarian Society. Accepted for publication, December, 1853. [May, 1855.] 4to., pp. 108, 61 woodcuts and 55 plates. (S. C. VII.)

71. Archæology of the United States, or sketches, historical and bibliographical, of the progress of information and opinion respecting vestiges of antiquity in the United States. By Samuel F. Haven. Accepted for publication, January, 1855. [July, 1856.] 4to., pp. 172. (S. C. VIII.)

72. A memoir on the extinct sloth tribe of North America. By Professor Joseph Leidy, M. D. Accepted for publication, December, 1853. [June, 1855.] 4to., pp. 70, and 16 plates. (S. C. VII.)

73. Appendix. Publications of learned societies and periodicals in the library of the Smithsonian Institution. Part I. [December 31, 1854.] [1855.] 4to., pp. 40. (S. C. VII.)

74. Catalogue of publications of the Smithsonian Institution. Corrected to June, 1862. 8vo., pp. 52. (M. C. V.)

75. Ninth annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution up to January 1, 1855, and the proceedings of the Board up to February 24, 1855. [33d Congress, 2d session, House of Representatives, Mis. Doc. No. 37.] 1855. 8vo., pp. 464, 4 woodcuts.

76. Smithsonian Contributions to Knowledge. Vol. VII. 1855. 4to. pp. 252, 70 woodcuts and 74 plates.

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(59.) Chappelsmith. Tornado near New Harmony, Indiana.
(63.) Bailey. New species and localities of microscopic organisms.
(70.) Lapham. Antiquities of Wisconsin.
(72.) Leidy. Extinct sloth tribe of North America.
(73.) Publications of societies and periodicals in Smithsonian Library. Part I.

77. Tenth annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution up to January 1, 1856, and the proceedings of the Board up to March 22, 1856. [34th Congress, 1st session, Senate Mis. Doc. No. 73.] 1856. 8vo., pp. 440, 79 woodcuts.

78. Smithsonian Contributions to Knowledge. Vol. VIII. 1856. 4to., pp. 556, 9 plates and 27 woodcuts.

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(71.) Haven. Archæology of the United States.
(81.) Olmsted. Recent secular period of aurora borealis.
(80.) Alvord. Tangencies of circles and of spheres.
(82.) Jones. Chemical and physiological investigations relative to vertebrata.
(84.) Force. Auroral Phenomena in Higher Northern Latitudes.
(85.) Publications of societies and periodicals in Smithsonian Library. Part II.

79. New tables for determining the values of the coefficients, in the perturbative function of planetary motion, which depend upon the ratio of the mean distances. By John D. Runkle. Accepted for publication, November, 1855. [November, 1856.] 4to., pp. 64. (S. C. IX.)

80. The tangencies of circles and of spheres. By Benjamin Alvord, major United States Army. Accepted for publication, January, 1855. [January, 1856.] 4to., pp. 16, 25 woodcuts and 9 plates. (S. C. VIII.)

81. On the recent secular period of the aurora borealis. By Professor Denison Olmsted, LL.D. Accepted for publication, January, 1855. [May, 1856.] 4to., pp. 52. (S. C. VIII.)

82. Investigations, chemical and physiological, relative to certain American vertebrata. By Professor Joseph Jones, M. D. Accepted for publication, March, 1856. [July, 1856.] 4to., pp. 150, and 27 woodcuts. (S. C. VIII.)

83. On the relative intensity of the heat and light of the sun upon different latitudes of the earth. By L. W. Meech, A. M. Accepted for publication, September, 1855. [November, 1856.] 4to., pp. 58, 5 woodcuts and 6 plates. (S. C. IX.)

84. Appendix. Record of auroral phenomena observed in the higher northern latitudes. Compiled by Peter Force. [July, 1856.] 4to., pp. 122. (S. C. VIII.)

85. Appendix. Publications of learned societies and periodicals in the library of the Smithsonian Institution. Part II. [May, 1856.] 4to., pp. 38. (S. C. VIII.)

86. Observations on Mexican history and archæology, with a special notice of Zapotec remains, as delineated in Mr. J. G. Sawkins's drawings of Mitla, Etc. By Brantz Mayer. Accepted for publication, June, 1856. [November, 1856.] 4to., pp. 36, 17 woodcuts and 4 plates. (S. C. IX.)

87. Psychrometrical table: for determining the elastic force of aqueous vapor, and the relative humidity of the atmosphere from indications of the wet and the dry bulb thermometer, Fahrenheit. By James H. Coffin, A. M. 1856. 8vo., pp. 20. (M. C. I.)

88. Researches on the ammonia-cobalt bases. By Wolcott Gibbs and Frederick Aug. Genth. Accepted for publication, July, 1856. [December, 1856.] 4to, pp. 72, 21 woodcuts. (S. C. IX.)

89. North American Oölogy. By Thomas M. Brewer, M. D. Part I.—Raptores and Fissirostres. Accepted for publication, February, 1856. [1857.] pp. 140, and 5 plates. (S. C. XI.)

90. Illustrations of surface geology. By Professor Edward Hitchcock, LL.D. Accepted for publication, January, 1856. [April, 1857.] 4to., pp. 164, 2 woodcuts and 12 plates. (S. C. IX.)

91. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1856, and the proceedings of the Board up to January 28, 1857. 34th Congress, 3d Session, House of Representatives, Mis. Doc. No. 55. 1857. 8vo., pp. 468; 69 woodcuts.

92. Smithsonian Contributions to Knowledge. Vol. IX. 1857. 4to., pp. 482, and 22 plates.

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(83.) Meech. Intensity of heat and light of sun upon different latitudes.
(90.) Hitchcock. Illustrations of surface geology.
(86.) Mayer. Mexican history and archæology, and Zapotec remains.
(88.) Gibbs and Genth. Researches on ammonia-cobalt bases.
(79.) Runkle. New tables, planetary motion.
(94.) Runkle. Asteroid supplement to new tables.

93. Smithsonian meteorological observations for the year 1855. (Printed for examination by the observers.) 1857. 8vo., pp. 118.

Printed merely to enable observers to verify their records, and distributed only to them. The same material is embodied in No. 157: "Results of Meteorological Observations," &c.

94. Asteroid supplement to new tables for determining the values of $b_s^{(i)}$ and its derivatives. By John D. Runkle. Accepted for publication November, 1855. [May, 1857.] 4to., pp. 72. (S. C. IX.)

95. Nereis Boreali-Americana: or, contributions to the history of the marine algæ of North America. Part III.—Chlorospermeæ. By Professor William Henry Harvey, M. D. Accepted for publication, September, 1857. [March, 1858.] 4to., pp. 142, and 14 plates, colored. (S. C. X.)

The colored plates are to be found in the extra copies, most of the edition inserted in the series of contributions having plain plates.

96. Nereis Boreali-Americana: or, contributions to a history of the marine algæ of North America. By Professor William Henry Harvey, M. D. In three parts, with 50 colored plates. May, 1858. 4to., pp. 568.

97. Magnetical observations in the Arctic Seas. By Elisha Kent Kane, M. D., U. S Navy. Made during the second Grinnell expedition in search

of Sir John Franklin, in 1853–'54–'55, at Van Rensselaer Harbor, and other points on the west coast of Greenland. Reduced and discussed by Charles A. Schott, assistant United States Coast Survey. Accepted for publication May, 1858. [1859.] 4to., pp. 72; one woodcut and two plates. (S. C. x.)

98. Grammar and dictionary of the Yoruba language. With an introductory description of the country and people of Yoruba. By the Rev. T. J. Bowen, Missionary of the Southern Baptist Convention. Accepted for publication May, 1858. [June, 1858.] 4to., pp. 232, and one map. (S. C. x.)

99. Smithsonian Contributions to Knowledge. Vol. X.* 1858. 4to., pp. 462, and 17 plates.

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(95.) Harvey. Marine algæ. Part III. Chlorospermeæ.
(97.) Kane. Magnetical observations in the Arctic seas.
(98.) Bowen. Grammar and dictionary of the Yoruba language.

100. An Account of the total eclipse of the sun on September 7, 1858, as observed near Olmos, Peru. By Lieutenant J. M. Gilliss. Accepted for publication, January, 1859. [April, 1859.] 4to., pp. 22; 1 woodcut and 1 plate. (S. C. xi.)

101. Map of the solar eclipse of March 15, 1858. By Rev. Thomas Hill, of Waltham, Massachusetts. Published by the Smithsonian Institution for distribution among its observers. January, 1858. 8vo., pp. 8, and one plate.

102. Catalogue of the described diptera of North America. Prepared for the Smithsonian Institution by R. Osten Sacken. January, 1858. 8vo., pp. 112. [With supplement of four pages. October, 1859.] (M. C. iii.)

103. Meteorological observations made at Providence, Rhode Island, extending over a period of twenty-eight years and a half, from December, 1831, to May, 1860. By Professor Alexis Caswell. Accepted for publication, August, 1859. [October, 1860.] 4to., pp. 188. (S. C. xii.)

104. Meteorological observations in the Arctic Seas. By Elisha Kent Kane, M. D., U. S. Navy. Made during the second Grinnell expedition in search of Sir John Franklin, in 1853, 1854, and 1855, at Van Rensselaer Harbor, and other points on the west coast of Greenland. Reduced and discussed by Charles, A. Schott, assistant United States Coast Survey. Accepted for publication May, 1858. [November, 1859.] 4to., pp. 120, 10 woodcuts. (S. C. xi.)

105. Catalogue of North American mammals, chiefly in the museum of the Smithsonian Institution. By Spencer F. Baird. July, 1857. 4to., pp. 22.

Reprinted from Vol. VIII of Pacific Railroad Report.

106. Catalogue of North American birds, chiefly in the museum of the Smithsonian Institution. By Spencer F. Baird. October, 1858. 4to., pp. 42.

Reprinted from Vol. IX of Pacific Railroad Report.

107. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1857. 35th Congress, 1st Session, Senate Mis. Doc. No. 272. 1858. 8vo., pp. 438; 100 woodcuts.

108. Catalogue of North American birds, chiefly in the museum of the Smithsonian Institution. By Spencer F. Baird. First octavo edition. 1859. 8vo., pp. 24. (M. C. II.)

Of this work an edition has been printed for labelling, with one side of each leaf blank.

109. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1858. 35th Congress, 2d Session, Senate Mis. Doc. No. 49. 1859. 8vo., pp. 448, 48 woodcuts.

110. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1859. 36th Congress, 1st Session, House of Representatives, Mis. Doc. No. 90. 1860. 8vo., pp. 450; 55 woodcuts.

111. Smithsonian Contributions to Knowledge. Vol. XI. 1859. 4to., pp. 506, and 23 plates.

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(89.) Brewer. North American Oölogy. Part I. Raptores and Fissirostres.
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112. Smithsonian Contributions to Knowledge. Vol. XII. 1860. Pages 540, 3 plates, and 12 woodcuts.

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(129.) Kane. Astronomical observations in the Arctic seas.
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(135.) Mitchell. Researches upon venom of the rattlesnake.

113. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Part I. Investigation of the eleven year period in the amplitude of the solar-diurnal variation and of the disturbances of the magnetic declination. By A. D. Bache, LL.D. Accepted for publication, June, 1859. [November, 1859.] 4to., pp. 22, 5 woodcuts. (S. C. XII.)

This paper forms Part I of Section 1 of the Discussion relating to the Declination.

114. Observations on terrestrial magnetism in Mexico. Conducted under the direction of Baron Von Müller, with notes and illustrations of an examination of the volcano Popocatapetl and its vicinity. By August Sonntag. Accepted for publication, May, 1859. [February, 1860.] 4to., pp. 92, 4 woodcuts, and one plate. (S. C. XI.)

115. Extracts from the proceedings of the Board of Regents of the Smithsonian Institution, in relation to the electro-magnetic telegraph. [1861.] 8vo., pp. 40, 7 woodcuts. [M. C. II.]

Reprinted from Proceedings of the Board of Regents for 1857.

116. List of public libraries, institutions, and societies in the United States and British provinces of North America. (From "Manual of Libraries," etc., by William J. Rhees.) 1859. 8vo., pp. 84.

117. Catalogue of publications of Societies and of other periodical works in the library of the Smithsonian Institution, July 1, 1858. Foreign works. 1859. 8vo., pp. 264. (M. C. III.)

118. Catalogue of the described lepidoptera of North America. Prepared for the Smithsonian Institution. By John G. Morris. May, 1860. 8vo., pp. 76. (M. C. III.)

119. On fluctuations of level in the North American lakes. By Charles Whittlesey. Accepted for publication, April, 1859. [July, 1860.] 4to., pp. 28, and 2 plates. (S. C. XII.)

120. Results of meteorological observations made at Marietta, Ohio, between 1826 and 1859, inclusive. By S. P. Hildreth, M. D.; to which are added results of observations taken at Marietta, by Mr. Joseph Wood, between 1817 and 1823. Reduced and discussed at the expense of the Smithsonian Institution. By Charles A. Schott. Accepted for publication, June, 1867. [September, 1867.] 4to., pp. 52, 14 woodcuts.

121. Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Part II.—Investigation of the solar-diurnal variation in the magnetic declination and its annual inequality. By A. D. Bache, LL.D. Accepted for publication, September, 1860. [June, 1862.] 4 to., pp. 28, 8 woodcuts. (S. C. XIII.)

122. Smithsonian Miscellaneous Collections. 1862. Vol. I. 8vo., pp. 738.

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(19.) (148.) Directions for meteorological observations.
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123. Smithsonian Miscellaneous Collections. 1862. Vol. II. 8vo., pp. 715.

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(27.) Booth and Morfit. Recent improvements in chemical arts.
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124. Smithsonian Miscellaneous Collections. Vol. III. 8vo., pp. 772.

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(102.) Osten Sacken. Catalogue diptera North America.
(118.) Morris. Catalogue described lepidoptera North America.
(136.) Le Conte. Classification coleoptera. I.
(117.) Catalogue publications of Societies in Smithsonian library.

125. Smithsonian Miscellaneous Collections. Vol. IV. 8vo., pp. 760.

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(134.) Hagen. Synopsis of North American neuroptera.
(133.) Morris. Synopsis of North American lepidoptera.

126. The coleoptera of Kansas and Eastern New Mexico. By John L. Le Conte, M. D. Accepted for publication, October 1859. [December, 1859.] pp. 64 and 3 plates. (S. C. XI.)

127. On certain storms in Europe and America, December, 1836. By Professor Elias Loomis, LL. D. Accepted for publication, August, 1859. [February, 1860.] 4to., pp. 28, and 13 plates. (S. C. XI.)

128. Check-lists of the shells of North America. Prepared for the Smithsonian Institution, by Isaac Lea, P. P. Carpenter, Wm. Stimpson, W. G. Binney, and Temple Prime. June, 1860. 8vo., pp. 52. (M. C. II.)

An edition for labelling has been printed with one side of each leaf blank.

129. Astronomical observations in the Arctic seas. By Elisha Kent Kane, M. D., U. S. N. Made during the second Grinnell expedition in search of Sir John Franklin, in 1853, 1854, and 1855, at Van Rensselaer Harbor, and other points in the vicinity of the northwest coast of Greenland. Reduced and discussed by Charles A. Schott, assistant United States Coast Survey. Accepted for publication, March, 1860. [May, 1860.] 4to., pp. 56, 3 woodcuts, and 1 plate. (S. C. XII.)

130. Tidal observations in the Arctic seas. By Elisha Kent Kane, M. D., U. S. N. Made during the second Grinnell expedition in search of Sir John Franklin, in 1853, 1854, and 1855, at Van Rensselaer harbor. Reduced and discussed, by Charles A. Schott, assistant United States Coast Survey. Accepted for publication, July, 1860. [October, 1860.] 4to., pp. 90, 3 woodcuts and 4 plates. (S. C. XIII.)

131. Meteorological observations made near Washington, Arkansas, extending over a period of twenty years, from 1840 to 1859, inclusive. By Nathan D. Smith, M. D. Accepted for publication, January, 1860. [October, 1860.] 4to., pp. 96. (S. C. XII.)

132. Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Part III.—Investigation of the influence of the moon on the magnetic declination. By A. D. Bache, LL.D. Accepted for publication, September, 1860. [June, 1862.] 4to., pp. 16, 3 woodcuts. (S. C. XIII.)

133. Synopsis of the described lepidoptera of North America. Part I.—Diurnal and crepuscular lepidoptera. Compiled for the Smithsonian Institu-

tion by John G. Morris. February, 1862. 8vo., pp. 386, and 30 woodcuts. (M. C. IV.)

134. Synopsis of the neuroptera of North America. With a list of the South American species. Prepared for the Smithsonian Institution by Hermann Hagen. July, 1861. 8vo., pp. 368. (M. C. IV.)

135. Researches upon the venom of the rattlesnake: with an investigation of the anatomy and physiology of the organs concerned. By S. Weir Mitchell, M. D. Accepted for publication, July, 1860. [December, 1860.] 4to., pp. 156, and 12 woodcuts.

136. Classification of the coleoptera of North America. Prepared for the Smithsonian Institution. By John L. Le Conte, M. D. 8vo., pp. 312, and 49 woodcuts. (M. C. III.)

Pages 1 to 208, published May, 1861; 209 to 278, March, 1862.

137. Circular to officers of the Hudson's Bay Company. 1860. 8vo., pp. 6.

138. Circular in reference to the degrees of relationship among different nations. [By Lewis H. Morgan. January, 1860.] 8vo., pp. 34. (M. C. II.)

139. Instructions in reference to collecting nests and eggs of North American birds. [January, 1860.] 8vo. Pages 22, and 20 woodcuts. Circular in reference to collecting nests and eggs of North American birds. 8vo. 12 pp. [February, 1861.] (M. C. II.)

140. List of the coleoptera of North America. Prepared for the Smithsonian Institution. By John L. Le Conte, M.D. Part I. March, 1863. April, 1866. 8vo., pp. 82. (M. C. VI.)

141. Monographs of the diptera of North America. Prepared for the Smithsonian Institution by H. Loew. Part I. Edited, with additions, by R. Osten Sacken. April, 1862. 8vo., pp. 246, with 15 woodcuts and 2 plates. (M. C. VI.)

142. Bibliography of North American conchology, previous to the year 1860. Prepared for the Smithsonian Institution. By W. G. Binney: Part I.—American Authors. March, 1863. 8vo., pp. 658. (M. C. V.)

143. Land and fresh-water shells of North America. Part II.—Pulmonata Limnophila and Thalassophila. By W. G. Binney. September, 1865. 8vo., pp. 172, 261 woodcuts. (M. C. VII.)

144. Land and fresh-water shells of North America. Part III.—Ampullariidæ, Valvatidæ, Viviparidæ, fresh-water Rissoidæ, Cyclophoridæ, Truncatellidæ, fresh-water Neritidæ, Helicinidæ. By W. G. Binney. September, 1865. 8vo., pp. 128, 232 woodcuts. (M. C. VII.)

145. Monograph of American corbiculadæ, (recent and fossil.) Prepared for the Smithsonian Institution. By Temple Prime. December, 1865. 8vo., pp. 92, 86 woodcuts. (M. C. VII.)

146. Meteorological observations in the Arctic seas. By Sir Francis Leopold M'Clintock, R. N. Made on board the Arctic searching yacht "Fox," in Baffin Bay and Prince Regent's Inlet, in 1857, 1858, and 1859. Reduced and discussed, at the expense of the Smithsonian Institution, by Charles A. Schott,

assistant United States Coast Survey. Accepted for publication, April, 1861. [May, 1862.] 4to., pp. 164, with 1 map and 14 woodcuts. (S. C. XIII.)

147. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1860. 36th Congress, 2d Session. House of Representatives Mis. Doc. 1861. 8vo., pp. 448, 73 woodcuts.

148. Directions for meteorological observations, and the registry of periodical phenomena. 1860. 8vo., pp. 72, 23 woodcuts. (M. C. I.)

149. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1861. 37th Congress, 2d Session, Mis. Doc. 1862. 8vo., pp. 464, 25 woodcuts.

150. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1862. 37th Congress, 3d Session, Mis. Doc. 1863. 8vo., pp. 446, 94 woodcuts.

151. Smithsonian Contributions to Knowledge. Vol. XIII. 1863. 4to., pp. 558, 7 plates, 70 woodcuts.

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(130.) Kane. Tidal observations, Arctic seas.
(146.) McClintock. Meteorological observations, Arctic seas.
(155.) Whittlesey. Ancient mining shores of Lake Superior.
(121.) Bache. Discussion, Girard College observations. Part II.
(132.) Bache. Discussion, Girard College observations. Part III.
(162.) Bache. Discussion, Girard College observations. Parts IV, V, VI.
(166.) Bache. Magnetic survey of Pennsylvania, &c.
(169.) Mitchell and Morehouse, researches upon anatomy and physiology of Chelonia.

152. Lectures on mollusca or "Shell-fish," and their allies. Prepared for the Smithsonian Institution. By Philip P. Carpenter, of Warrington, England. 1861. 8vo., pp. 140.

153. Tables, meteorological and physical, prepared for the Smithsonian Institution. By Arnold Guyot, P. D., LL.D. Third edition, revised and enlarged. 1859. 8vo., pp. 638. (M. C. I.)

154. List of foreign correspondents of the Smithsonian Institution. Corrected to January, 1862. May, 1862. 8vo., pp. 56. (M. C. V.)

155. Ancient mining on the shores of Lake Superior. By Charles Whittlesey. Accepted for publication April, 1862. [April, 1863.] 4to., pp. 34, 1 map, 21 woodcuts. (S. C. XIII.)

156. Catalogue of minerals, with their formulas, etc. Prepared for the Smithsonian Institution by T. Egleston. June, 1863. 8vo., pp. 56. (M. C. VII.)

157. Results of meteorological observations, made under the direction of the United States Patent Office and the Smithsonian Institution, from the year 1854 to 1859, inclusive, being a report of the Commissioner of Patents made at the first session of the 36th Congress. Vol. I. 1861. 4to., pp. 1270.

36th Congress, 1st Session, Senate Ex. Doc.

158. Smithsonian Miscellaneous Collections. 1864. Vol. V. 8vo., pp. 774.

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(142.) Binney. Bibliography of North American conchology.
(74.) Catalogue of publications of the Smithsonian Institution to June, 1862.
(154.) List of foreign correspondents of the Smithsonian Institution to January, 1862.

159. Researches upon the anatomy and physiology of respiration in the Chelonia. By S. Weir Mitchell, M. D., and George R. Morehouse, M. D. Accepted for publication, March, 1863. April, 1863. 4to., pp. 50, 10 woodcuts. (S. C. XIII.)

160. Instructions for research relative to the ethnology and philology of America. Prepared for the Smithsonian Institution. By George Gibbs. March, 1863. 8vo., pp. 56. (M. C. VII.)

161. A Dictionary of the chinook jargon, or trade language of Oregon. Prepared for the Smithsonian Institution. By George Gibbs. March, 1863. 8vo, pp. 60. (M. C. VII.)

162. Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Second section, comprising Parts IV, V, and VI. Horizontal force. Investigation of the eleven (or ten) year period and of the disturbances of the Horizontal component of the magnetic force, with an investigation of the solar-diurnal variation, and of the annual inequality of the horizontal force, and of the lunar effect on the same. By A. D. Bache, LL.D., F. R. S. Accepted for publication, June, 1862. [November, 1862.] 4to., pp. 78, 11 woodcuts. (S. C. XIII.)

163. Circular in reference to the history of North American grasshoppers. [January, 1860.] Pp. 4. (M. C. II.)

164. Smithsonian museum miscellanea. 1862. Pp. 88.

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(1.) Abbreviations of names of States and Territories of North America, for labelling insects, shells, &c.
(2.) A series of small figures, from 1–1643.
(3.) A series of medium figures, from 1–2747.
(4.) A series of large figures, from 1–2599.
(5.) Blank check-list of specimens.

No. 5 consists of columns of figures from 1 to 1,000, and of two series, 25 and 50, to the 8vo. column. All these are stereotyped and printed with from one to eight columns on each page, with blank spaces of greater or less extent, as may be required.

165. Monograph of the bats of North America. By H. Allen, M. D., assistant surgeon United States Army. June, 1864. 8vo., pp. 110, and 73 woodcuts. (M. C. VII.)

166. Records and results of a magnetic survey of Pennsylvania and parts of adjacent States, in 1840 and 1841, with some additional records and results of 1834, 1835, 1843 and 1862, and a map. By A. D. Bache, LL.D., F. R. S.

Accepted for publication, February, 1863. [October, 1863.] 4to., pp. 88, 1 map. (S. C. XIII.)

167. New species of North American coleoptera. Prepared for the Smithsonian Institution. By John L. Le Conte, M. D. Part I. March, 1863. April, 1866. 8vo., pp. 180. (M. C. VI.)

168. Circular relative to collections of birds from middle and South America. [December, 1863.] 8vo., pp. 2.

169. Smithsonian Miscellaneous Collections. Vol. VI. 8vo., pp. 888, 3 woodcuts, 2 plates.

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(141.) Loew. Monograph of diptera. Part I.
(171.) Loew. Monograph of diptera. Part II.
(140.) Le Conte. List of coleoptera of North America.
(167.) Le Conte. New species of North American coleoptera.

170. Comparative vocabulary. (Reprinted from Smithsonian instructions in ethnology and philology.) May, 1863. 4to., pp. 20.

171. Monographs of the diptera of North America. Prepared for the Smithsonian Institution. By H. Loew. Part II. Edited by R. Osten Sacken. January, 1864. 8vo., pp. 372, 5 plates. (M. C. VI.)

172. Palæontology of the upper Missouri; a report upon collections made principally by the expeditions under command of Lieutenant G. K. Warren, United States topographical engineers, in 1855 and 1856. Invertebrates. By F. B. Meek and F. V. Hayden, M. D. Part I. Accepted for publication May 1864. [April, 1865.] 4to., pp. 158, 5 plates, 31 woodcuts. (S. C. XIV.)

173. The gray substance of the medulla oblongata and trapezium. By John Dean, M. D. Accepted for publication August, 1863. [February, 1864.] 4to., pp. 80, 16 plates, 5 woodcuts.

174. Bibliography of North American conchology previous to the year 1860. Prepared for the Smithsonian Institution. By W. G. Binney. Part II. Foreign authors. June, 1864. 8vo., pp. 302.

175. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Third Section, comprising Parts VII, VIII, and IX. Vertical force. Investigation of the eleven (or ten) year period and of the disturbances of the vertical component of the magnetic force, and appendix on the magnetic effect of the aurora borealis; with an investigation of the solar-diurnal variation, and of the annual inequality of the vertical force; and of the lunar effect on the vertical force, the inclination, and total force. By A. D. Bache, LL.D., F. R. S. Accepted for publication August, 1863. [April, 1864.] 4to., pp. 72, 14 woodcuts. (S. C. XIV.)

176. Circular in reference to collecting North American shells. January, 1860. pp. 4. (M. C. II.)

177. Check-list of the invertebrate fossils of North America. Cretaceous and jurassic. By F. B. Meek. April, 1864. 8vo., pp. 42. (M. C. VII.)

178. Circular to entomologists. 1860. 8vo., pp. 2.

179. Catalogue of publications of societies and of periodical works, belonging to the Smithsonian Institution, January 1, 1866. Deposited in the library of Congress. 1866. 8vo., pp. 596.

180. On the construction of a silvered glass telescope, fifteen and a half inches in aperture, and its use in celestial photography. By Henry Draper, M. D. Accepted for publication, January, 1864. [July, 1864.] 4to., pp., 60, 47 woodcuts. (S. C. XIV.)

181. Review of American birds, in the museum of the Smithsonian Institution. By S. F. Baird. Part I.—North and middle America. [June, 1864—June, 1866.] 8vo., pp. 454, 86 woodcuts.

182. Results of meteorological observations made under the direction of the United States Patent Office and the Smithsonian Institution, from the year 1854 to 1859, inclusive, being a report of the Commissioner of Patents made at the 1st Session of the 36th Congress. Vol. II. Part I. 36th Congress, 1st Session. Senate Ex. Doc. 1864. 4to., pp. 546.

183. Check-list of the invertebrate fossils of North America. Miocene. By F. B. Meek. November, 1864. 8vo., pp. 34. (M. C. VII.)

184. Smithsonian Contributions to Knowledge. Vol. XIV. 1865. Pages 490, 25 plates, 131 woodcuts.

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(175.) Bache. Discussion Girard College observations. Parts VII, VIII, IX.
(186.) Bache. Discussion Girard College observations. Parts X, XI, XII.
(180.) Draper. Construction of silvered glass telescope and its use in celestial photography.
(172.) Meek and Hayden. Palæontology of the Upper Missouri.
(192.) Leidy. Cretaceous reptiles of the United States.

185. List of the described birds of Mexico, Central America, and the West Indies not in the collection of the Smithsonian Institution. January 1. 1863. 8vo., pp. 8.

186. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Fourth section, comprising Parts X, XI, and XII. Dip and total force; analysis of the disturbances of the dip and total force; discussion of the solar diurnal variation and annual inequality of the dip and total force; and discussion of the absolute dip, with the final values for declination, dip and force between 1841 and 1845. By A. D. Bache, LL. D., F. R. S. Accepted for publication, May, 1864. [April, 1865.] 4to., pp. 42, 8 woodcuts. (S. C. XIV.)

187. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1863. 38th Congress, 1st Session. House of Representatives. Misc. Doc. No. 83. 1864. 8vo., pp. 420, 56 woodcuts.

188. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1864. 1865. 8vo., pp. 450, 50 woodcuts.

189. Catalogue of the orthoptera of North America described previous to 1867. Prepared for the Smithsonian Institution. By Samuel H. Scudder. October, 1868. 8vo., pp. 110.

190. Queries relative to tornadoes. 8vo., pp. 4, 1 woodcut.

191. Smithsonian Miscellaneous Collections. Vol. VII. 8vo., pp. 878. 676 woodcuts.

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(165.) Allen. Monograph of bats of North America.
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(160.) Gibbs. Instructions for ethnological and philological research.
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194. Land and fresh-water shells of North America. Part I.—Pulmonata geophila. By W. G. Binney and T. Bland. February, 1869. 8vo., pp. 328; woodcuts.

195. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845. Parts I to XII inclusive. 4to., pp. 262, 49 woodcuts.

196. Physical observations in the Arctic seas. By Isaac I. Hayes, M. D., commanding expedition. Made on the west coast of north Greenland, the vicinity of Smith strait and the west side of Kennedy channel, during 1860 and 1861. Reduced and discussed at the expense of the Smithsonian Institution. By Charles A. Schott. Accepted for publication, February, 1865. [June, 1867.] 4to., pp. 286, 15 woodcuts, and 6 plates. (S. C. XV.) [Contains astronomical, magnetic, tidal, and meteorological observations.]

197. On the fresh-water glacial drift of the northwestern states. By Charles Whittlesey. Accepted for publication, June, 1864. [May, 1866.] 4to., pp. 38, 2 maps, and 11 woodcuts. (S. C. XV.)

198. Physical observations in the Arctic seas. By Elisha Kent Kane, M. D., United States Navy. Made during the second Grinnell expedition in search of Sir John Franklin, in 1853, 1854, and 1855, at Van Rensselaer harbor and other points on the west coast of Greenland. Reduced and discussed for the Smithsonian Institution. By Charles A. Schott. Part I.—Magnetism. II.—

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199. An investigation of the orbit of Neptune, with general tables of its motion. By Simon Newcomb, Professor of mathematics, United States navy. Accepted for publication, May, 1865. [January, 1866.] 4to., pp. 116. (S. C. XV.)

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206. Smithsonian Contributions to Knowledge. Vol. XV. 1867. pp. 620, 17 plates, and 43 woodcuts.

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214. Annual report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year 1866. 39th Congress, 2d Session. House of Representatives, Mis. Doc. No. 83. 1867. 8vo., pp. 470, 70 woodcuts.

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